https://arxiv.org/abs/1401.0170

https://arxiv.org/abs/1409.8570

https://arxiv.org/abs/0904.4681

https://arxiv.org/abs/1201.3002

https://arxiv.org/abs/1008.2503

https://arxiv.org/abs/1409.6223

https://arxiv.org/abs/1011.4433

https://arxiv.org/abs/1308.5983

https://arxiv.org/abs/1107.2893

https://arxiv.org/abs/0712.1704

https://arxiv.org/abs/1308.1824

https://arxiv.org/abs/1107.4144

https://arxiv.org/abs/1008.1564

https://arxiv.org/abs/1307.0984

https://arxiv.org/abs/1411.6894

https://arxiv.org/abs/0810.1205

https://arxiv.org/abs/1010.5625

https://arxiv.org/abs/1203.2855

https://arxiv.org/abs/1104.5175

https://arxiv.org/abs/1409.3286

https://arxiv.org/abs/1308.0986

https://arxiv.org/abs/1309.3617

https://arxiv.org/abs/1010.1537

https://arxiv.org/abs/1210.3487

https://arxiv.org/abs/1002.2528

https://arxiv.org/abs/1303.6458

https://arxiv.org/abs/0708.0088

https://arxiv.org/abs/0809.0798

https://arxiv.org/abs/0803.0949

https://arxiv.org/abs/0911.0289

https://arxiv.org/abs/1601.02210

https://arxiv.org/abs/1804.06310

https://arxiv.org/abs/1904.00630

https://arxiv.org/abs/2004.00450

https://arxiv.org/abs/2007.02850

https://arxiv.org/abs/1812.05950

https://arxiv.org/abs/1906.00160

https://arxiv.org/abs/1810.05660

https://arxiv.org/abs/1805.02470

https://arxiv.org/abs/1610.04970

https://arxiv.org/abs/1603.00901

https://arxiv.org/abs/1703.03211

https://arxiv.org/abs/2004.07121

https://arxiv.org/abs/1603.04331

https://arxiv.org/abs/1505.06641

https://arxiv.org/abs/1603.05351

https://arxiv.org/abs/1803.07061

https://arxiv.org/abs/1503.07571

https://arxiv.org/abs/1605.02671

https://arxiv.org/abs/1901.10291

https://arxiv.org/abs/1508.03102

https://arxiv.org/abs/1510.01802

https://arxiv.org/abs/1611.08112

https://arxiv.org/abs/1606.07612

https://arxiv.org/abs/1802.00712

https://arxiv.org/abs/2002.05042

https://arxiv.org/abs/1505.06642

https://arxiv.org/abs/1610.08852

https://arxiv.org/abs/1811.04952

https://arxiv.org/abs/1906.05952

https://arxiv.org/abs/1510.04262

https://arxiv.org/abs/1710.03862

https://arxiv.org/abs/1909.09062

https://arxiv.org/abs/1503.00372

https://arxiv.org/abs/1508.06372

https://arxiv.org/abs/1910.07472

https://arxiv.org/abs/1811.00772

https://arxiv.org/abs/1602.06772

https://arxiv.org/abs/1906.06082

https://arxiv.org/abs/2004.08082

https://arxiv.org/abs/1705.08892

https://arxiv.org/abs/2001.11982

https://arxiv.org/abs/1901.09213

https://arxiv.org/abs/1708.03913

https://arxiv.org/abs/1904.03523

https://arxiv.org/abs/1506.00723

https://arxiv.org/abs/1804.00723

https://arxiv.org/abs/1710.02433

https://arxiv.org/abs/1608.03433

https://arxiv.org/abs/1712.08433

https://arxiv.org/abs/1809.09543

https://arxiv.org/abs/1807.10663

https://arxiv.org/abs/1905.06273

https://arxiv.org/abs/1812.09983

https://arxiv.org/abs/1911.05393

https://arxiv.org/abs/2002.09104

https://arxiv.org/abs/1812.01304

https://arxiv.org/abs/1911.12214

https://arxiv.org/abs/1505.01764

https://arxiv.org/abs/1705.04694

https://arxiv.org/abs/1905.11405

https://arxiv.org/abs/1608.08605

https://arxiv.org/abs/1608.06625

https://arxiv.org/abs/1803.00635

https://arxiv.org/abs/1509.00945

https://arxiv.org/abs/1905.02455

https://arxiv.org/abs/1810.00665

https://arxiv.org/abs/2004.02175

https://arxiv.org/abs/1512.07375

https://arxiv.org/abs/1604.05475

https://arxiv.org/abs/1905.11285

https://arxiv.org/abs/1601.05895

https://arxiv.org/abs/1805.04206

https://arxiv.org/abs/1806.04116

https://arxiv.org/abs/1512.09316

https://arxiv.org/abs/1708.08516

https://arxiv.org/abs/1511.03336

https://arxiv.org/abs/1701.07876

https://arxiv.org/abs/1603.08846

https://arxiv.org/abs/2004.06356

https://arxiv.org/abs/1805.09286

https://arxiv.org/abs/1705.00196

https://arxiv.org/abs/1801.07396

https://arxiv.org/abs/1903.10996

https://arxiv.org/abs/1505.00307

https://arxiv.org/abs/1607.00907

https://arxiv.org/abs/1502.03807

https://arxiv.org/abs/2003.11327

https://arxiv.org/abs/1908.02727

https://arxiv.org/abs/1905.13527

https://arxiv.org/abs/1511.02827

https://arxiv.org/abs/2001.08037

https://arxiv.org/abs/1605.04647

https://arxiv.org/abs/1805.06857

https://arxiv.org/abs/1810.04867

https://arxiv.org/abs/1506.06577

https://arxiv.org/abs/1610.07197

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https://arxiv.org/abs/1804.00797

https://arxiv.org/abs/1703.02708

https://arxiv.org/abs/1705.05708

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https://arxiv.org/abs/1904.08148

https://arxiv.org/abs/2012.09358

https://arxiv.org/abs/1711.06958

https://arxiv.org/abs/1609.02078

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https://arxiv.org/abs/1606.05178

https://arxiv.org/abs/1807.02678

https://arxiv.org/abs/1704.04898

https://arxiv.org/abs/1811.03709

https://arxiv.org/abs/1505.05249

https://arxiv.org/abs/1712.03749

https://arxiv.org/abs/1508.06649

https://arxiv.org/abs/1901.01749

https://arxiv.org/abs/1902.06159

https://arxiv.org/abs/2005.07969

https://arxiv.org/abs/1809.07389

https://arxiv.org/abs/1703.02040

https://arxiv.org/abs/2002.03940

https://arxiv.org/abs/1601.04239a

https://arxiv.org/abs/1608.01762v1

https://arxiv.org/abs/1704.07194v1

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https://arxiv.org/abs/cond-mat/9906421

https://arxiv.org/abs/cond-mat/0105432

https://arxiv.org/abs/cond-mat/0510404

https://arxiv.org/abs/cond-mat/0309124

https://arxiv.org/abs/cond-mat/0311474

https://arxiv.org/abs/cond-mat/9807384

https://arxiv.org/abs/cond-mat/9912494

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https://arxiv.org/ftp/arxiv/papers/1601/1601.02735.pdf

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https://arxiv.org/ftp/arxiv/papers/1607/1607.02886.pdf

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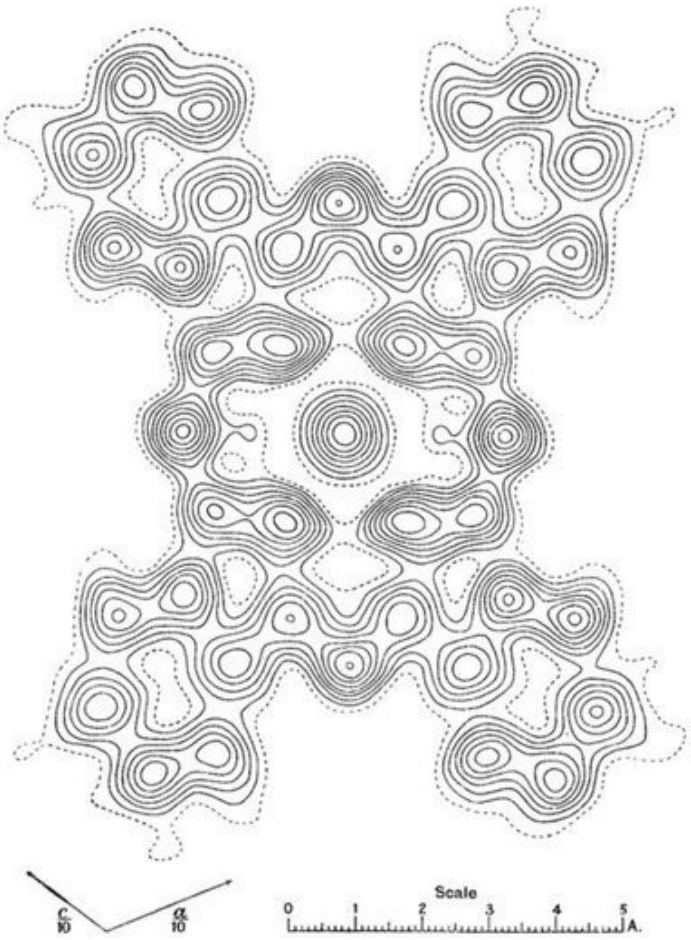
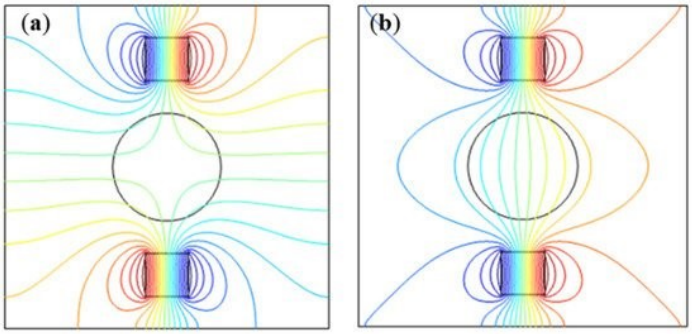
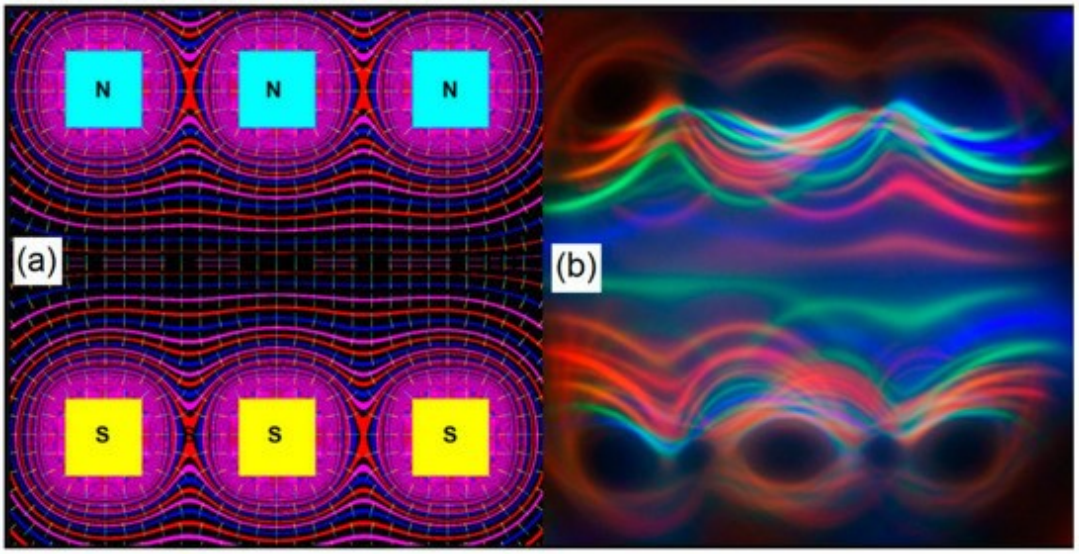
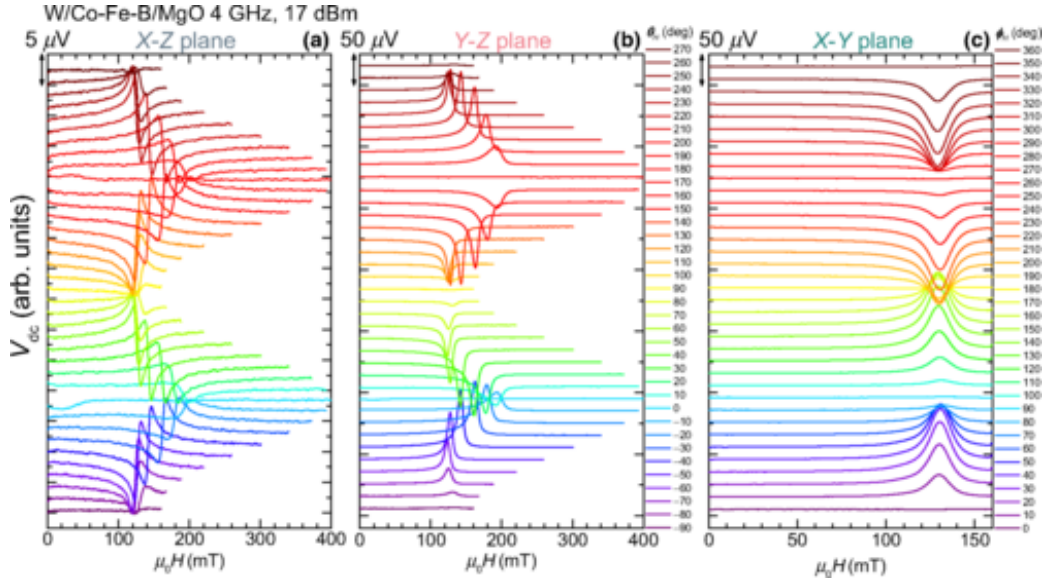
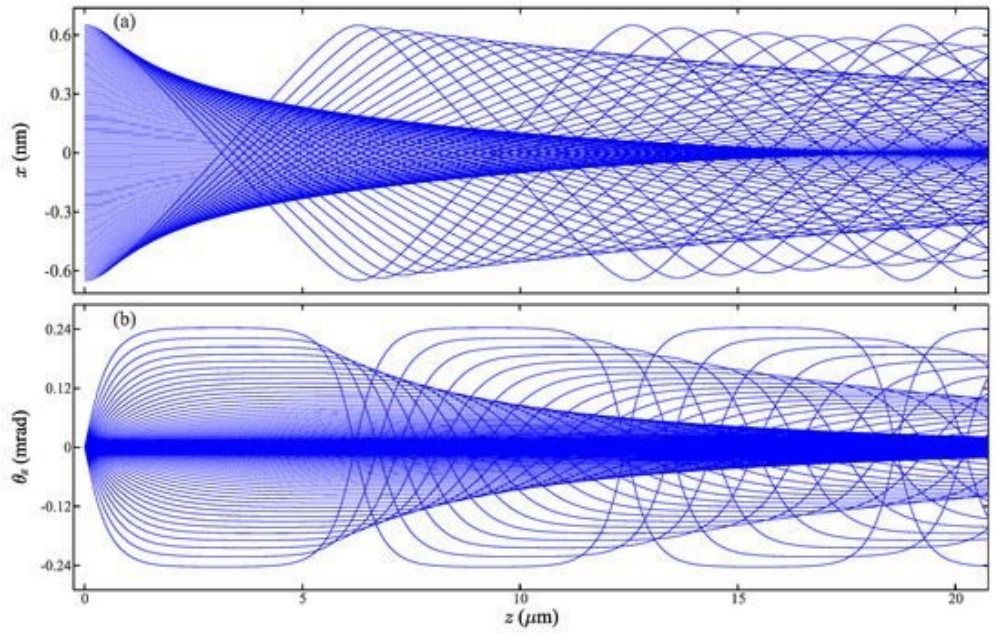
https://www.researchgate.net/publication/51595280_Spin-Glass_Transition_in_Bond-Disordered_Heisenberg_Antiferromagnets_Coupled_with_Local_Lattice_Distortions_on_a_Pyrochlore_Lattice

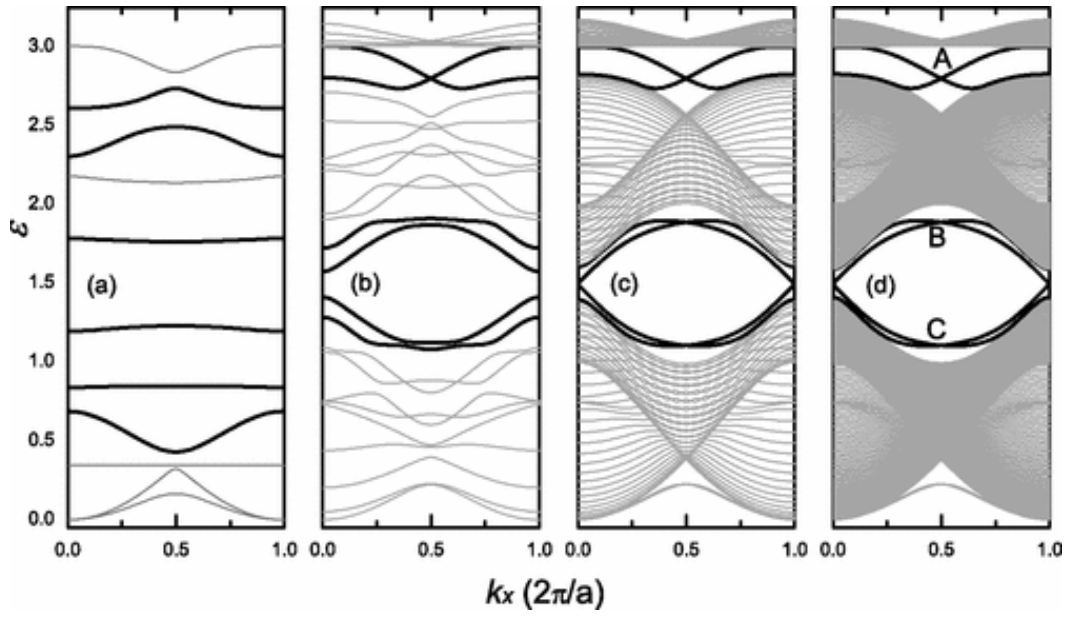

c
10
a
10
Scale
0
1
2
3
4
5
A.

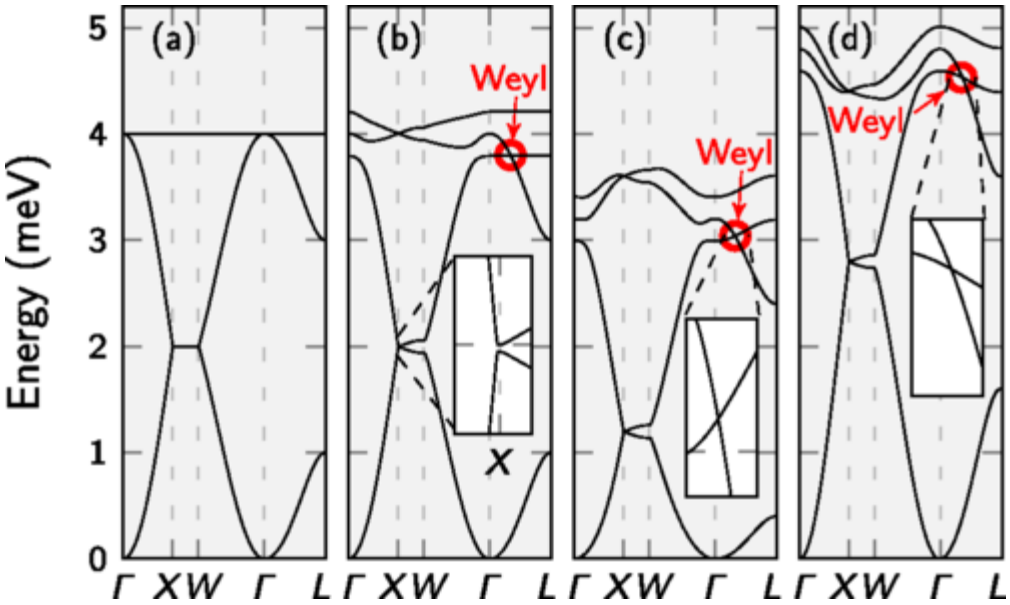

(a)
(b)

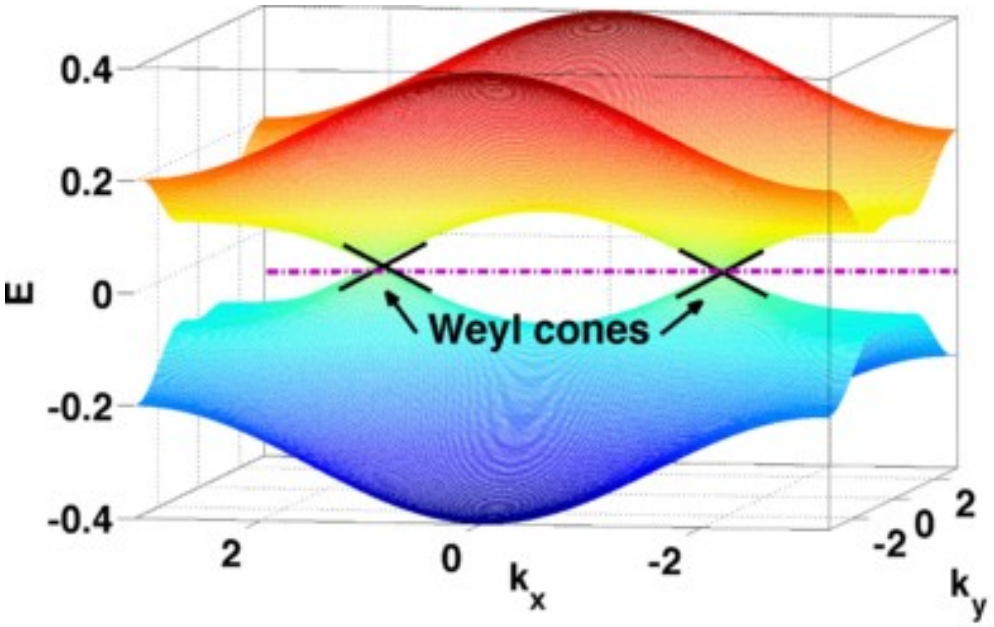

N
N
N
(a)
S
S
S
(b)

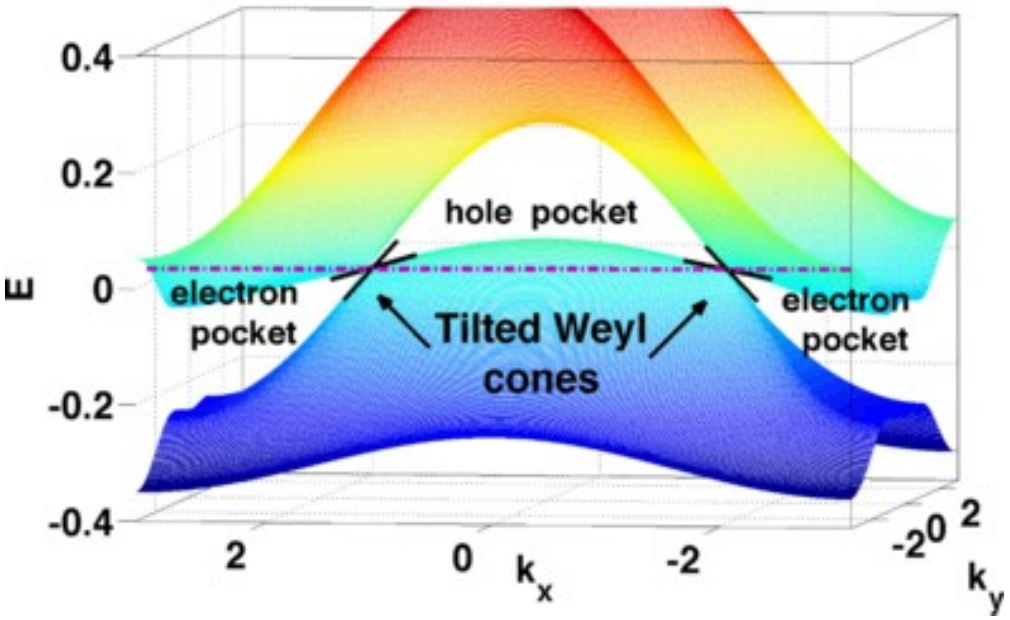

W/Co-Fe-B/MgO 4 GHz, 17 dBm
5 μV
X-Z plane
(a)
50 μV
Y-Z plane
(b)
50 μV
X-Y plane
(c)
V_dc (arb. units)
μ0H (mT)

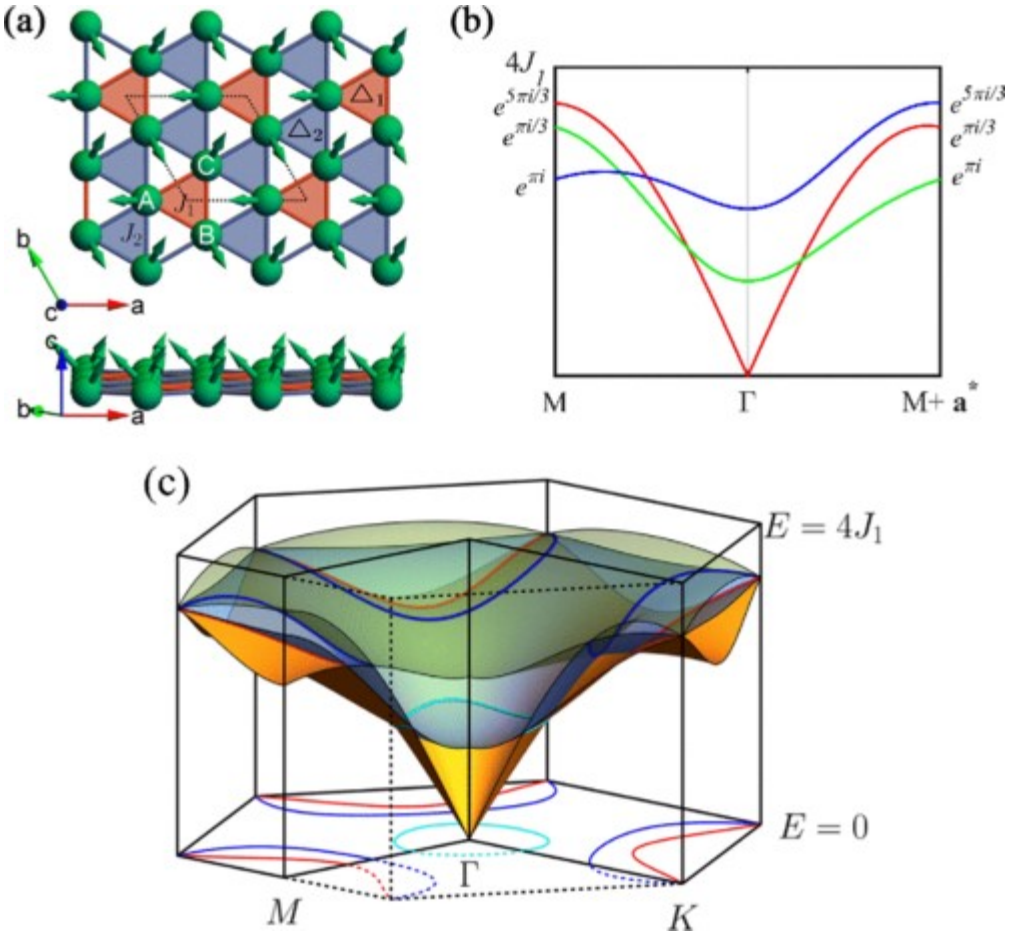

(a)
x (nm)
(b)
θx (mrad)
z (μm)

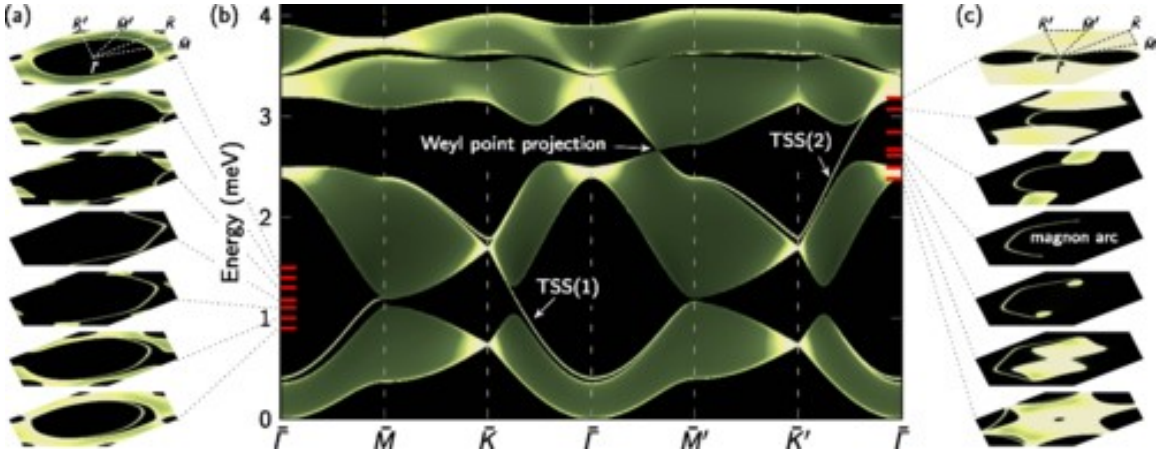

ε
(a)
(b)
(c)
(d)
A
B
C
kx (2π/a)

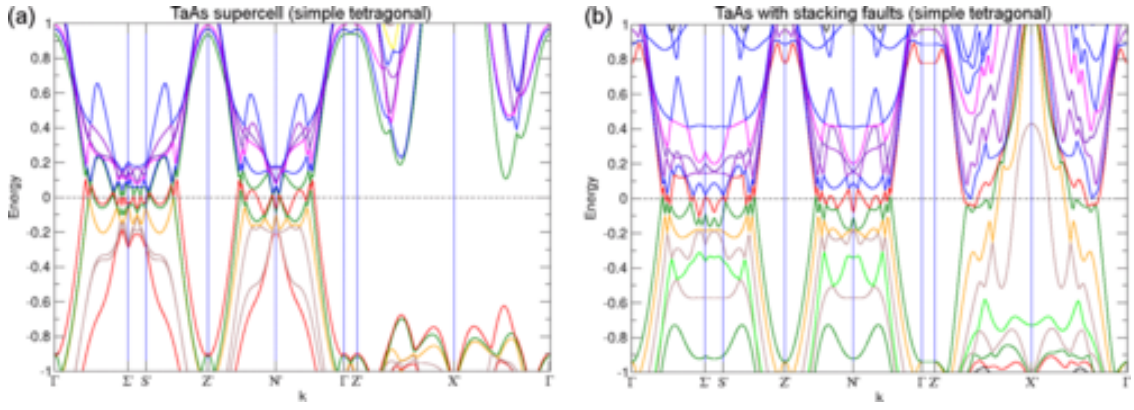

(a)
(b)
(c)
(d)
Weyl
Weyl
Weyl
X
Energy (meV)
5
4
3
2
1
0
Γ X W Γ L

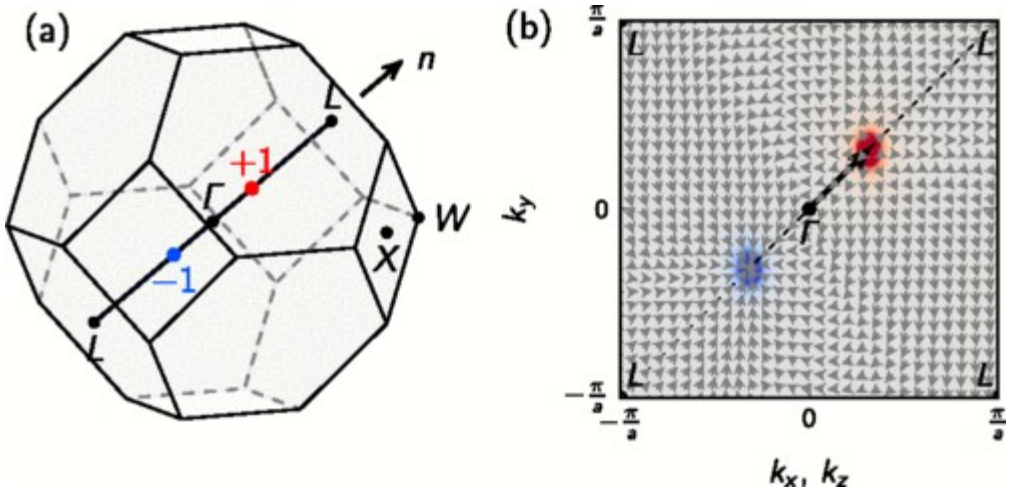

0.4
0.2
0
-0.2
-0.4
E
Weyl cones
2
0
-2
k_x
-2
0
2
k_y

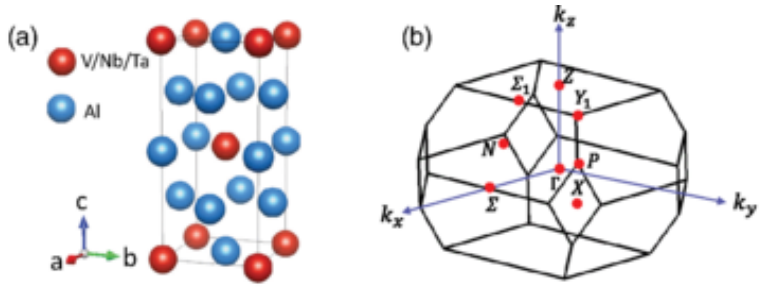

0.4
0.2
0
-0.2
-0.4
E
hole pocket
electron pocket
electron pocket
Tilted Weyl cones
2
0
-2
k_x
-2
0
2
k_y

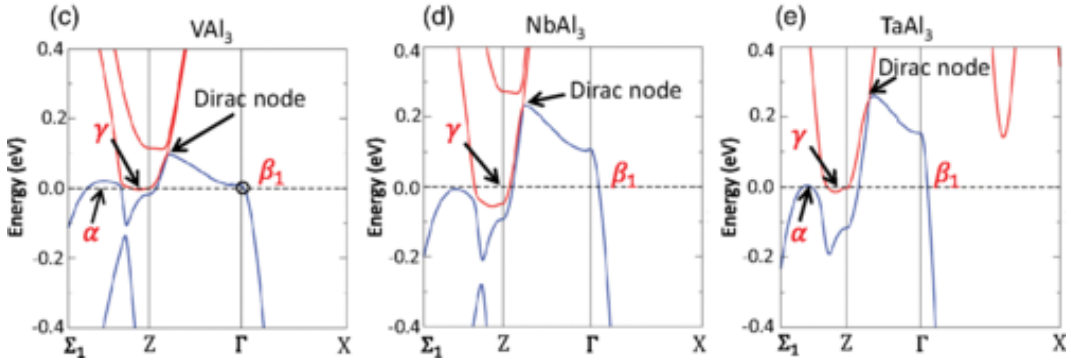

(a)
A
B
C
$\triangle_1$
$\triangle_2$
J_1
J_2
b
a
c
(b)
$4J_1$
$e^{5\pi i/3}$
$e^{\pi i/3}$
$e^{\pi i}$
M
Γ
M+ a*
(c)
$E = 4J_1$
$E = 0$
Γ
M
K

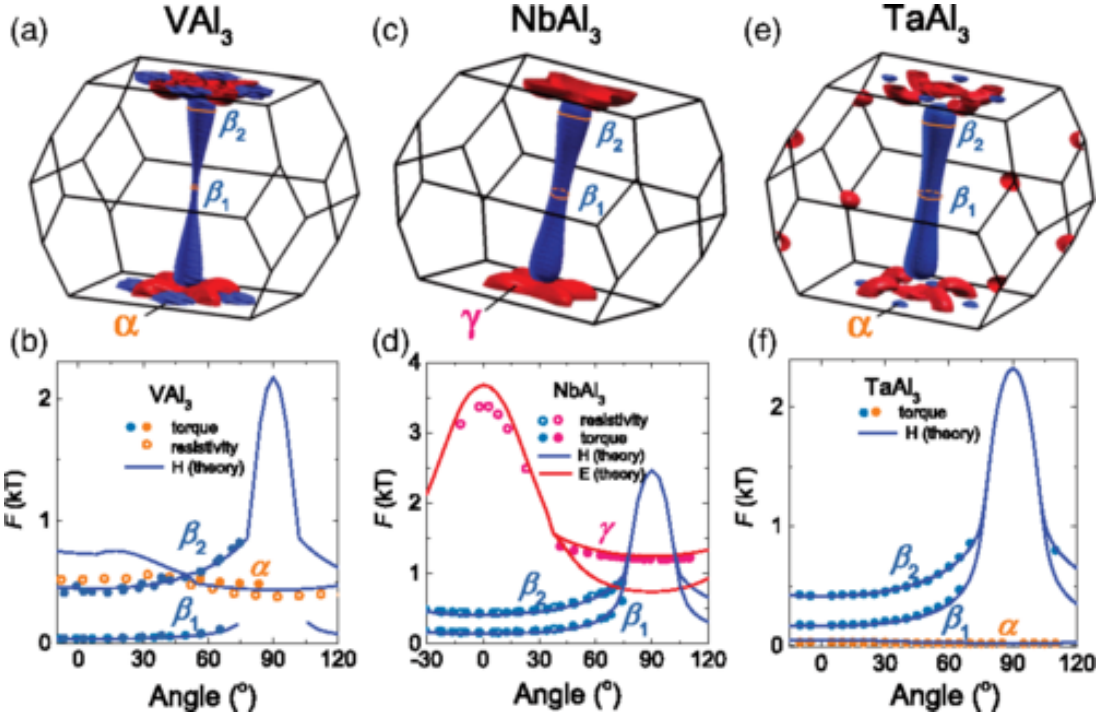

(a)
(b)
(c)
Energy (meV)
Weyl point projection
TSS(2)
TSS(1)
magnon arc
$\bar{\Gamma}$
$\bar{M}$
$\bar{K}$
$\bar{\Gamma}$
$\bar{M}'$
$\bar{K}'$
$\bar{\Gamma}$

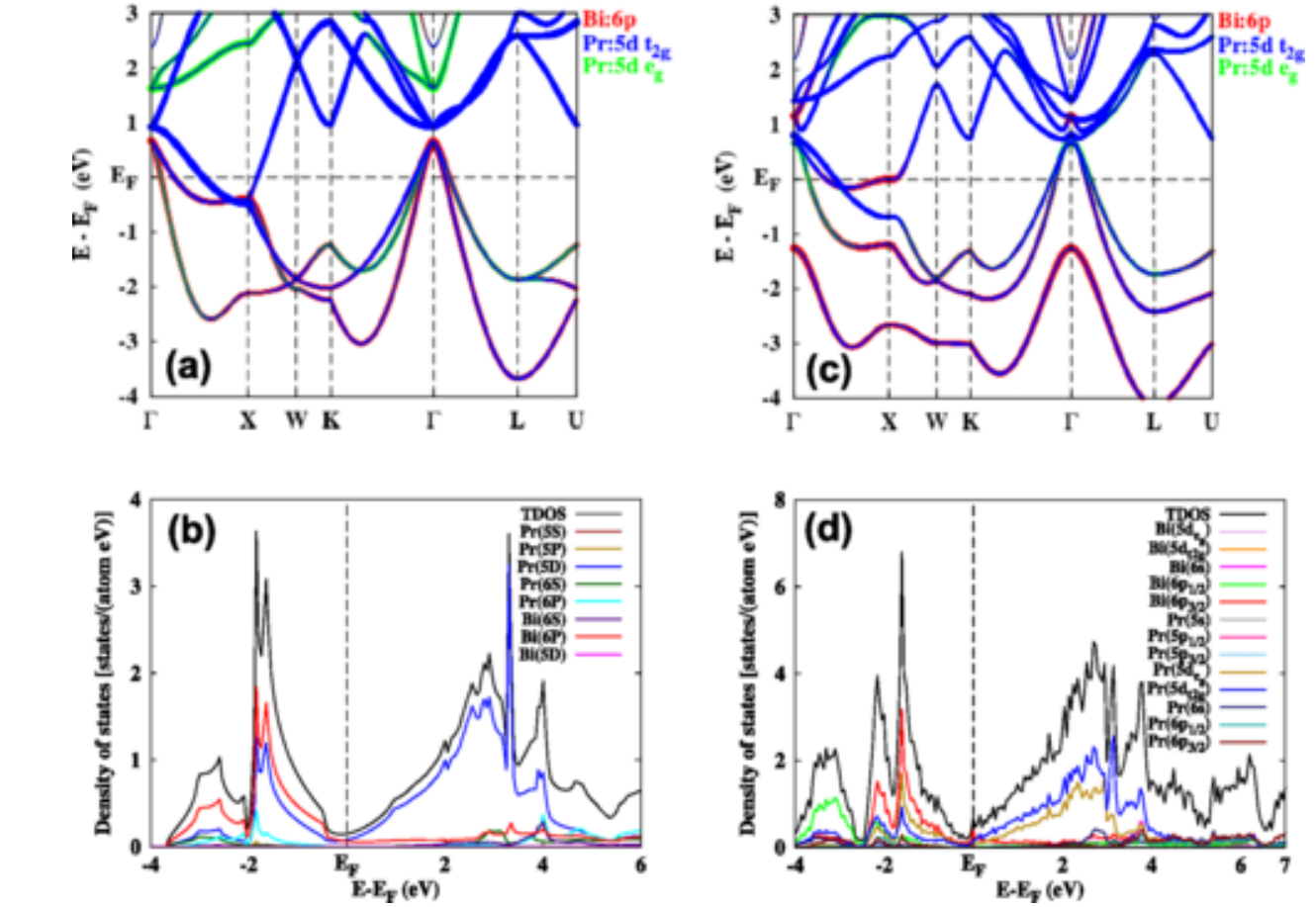

(a)
TaAs supercell (simple tetragonal)
(b)
TaAs with stacking faults (simple tetragonal)
Energy
k
Γ
Σ S
Z
N
Γ Z
X
Γ


(a)
n
L
+1
Γ
W
X
−1
L
(b)
L
L
Γ
L
L
k_y
k_x, k_z
0

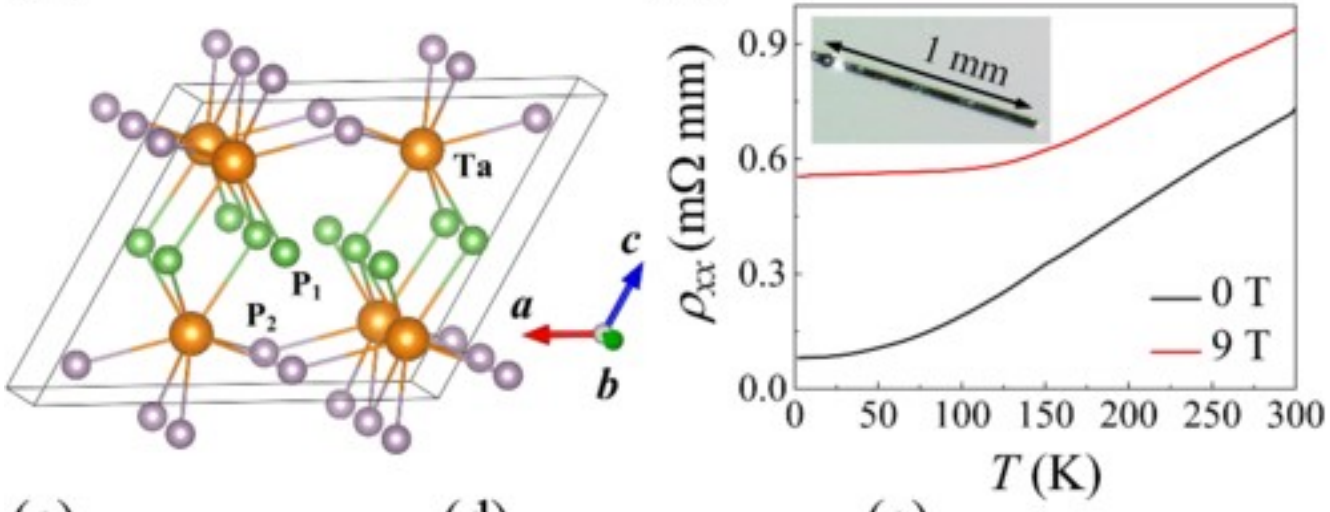

(a)
V/Nb/Ta
Al
c
a
b
(b)
k_z
Σ_1
Z
Y_1
N
P
Γ
X
Σ
k_x
k_y


(c)
VAl_3
(d)
$NbAl_3$
(e)
$TaAl_3$
Dirac node
Dirac node
Dirac node
γ
β_1
α
Energy (eV)
0.4
0.2
0.0
-0.2
-0.4
Σ_1
Z
Γ
X

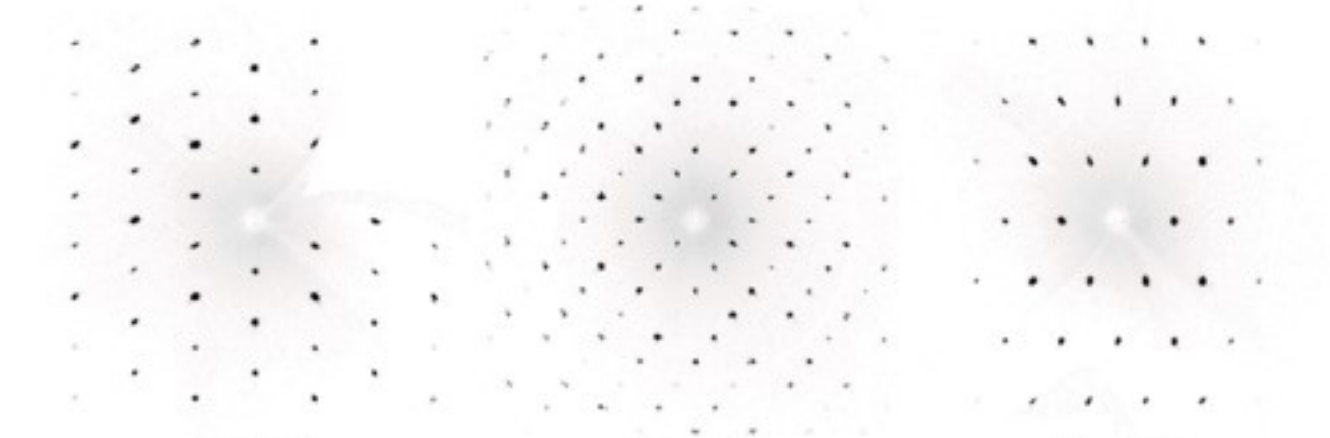

(a)
VAl_3
(c)
$NbAl_3$
(e)
$TaAl_3$
β_2
β_1
α
γ
(b)
(d)
(f)
torque
resistivity
H (theory)
E (theory)
F (kT)
Angle (°)
0
30
60
90
120
-30



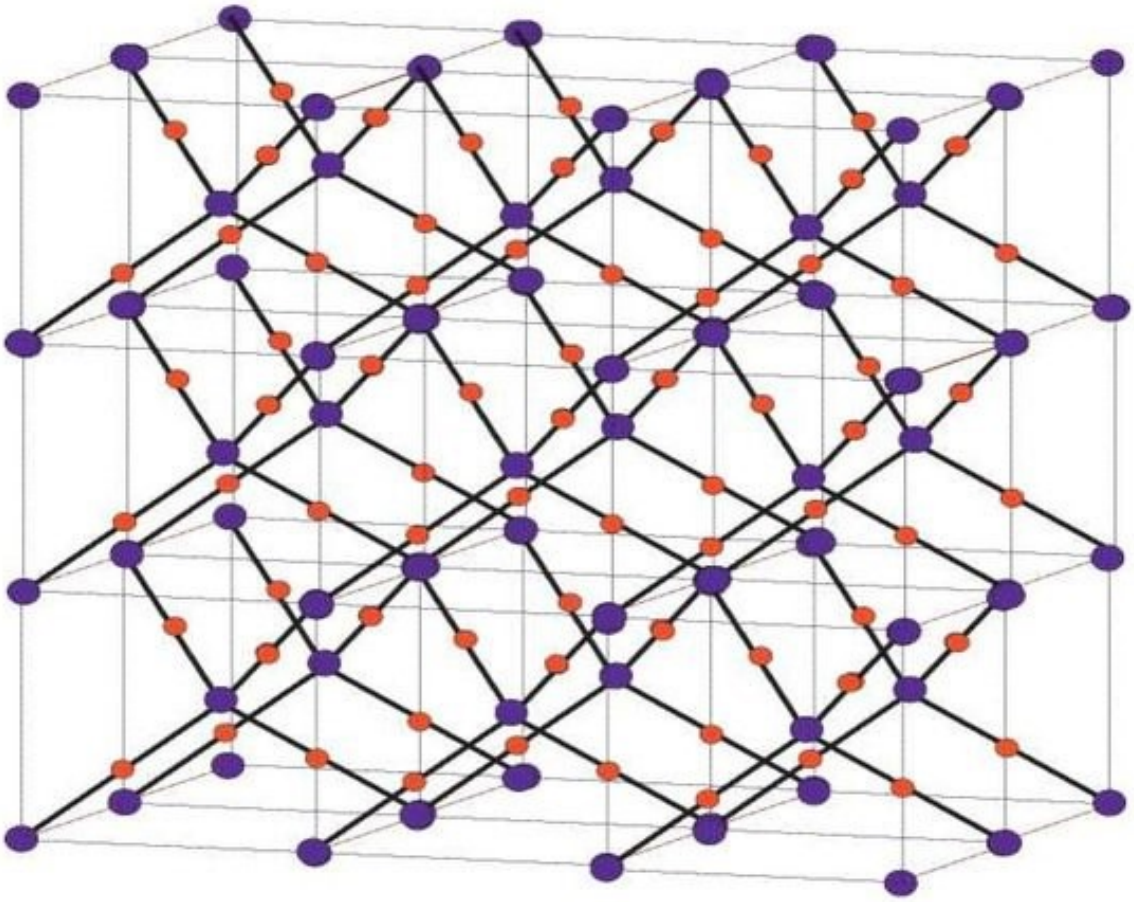
(a) (b)

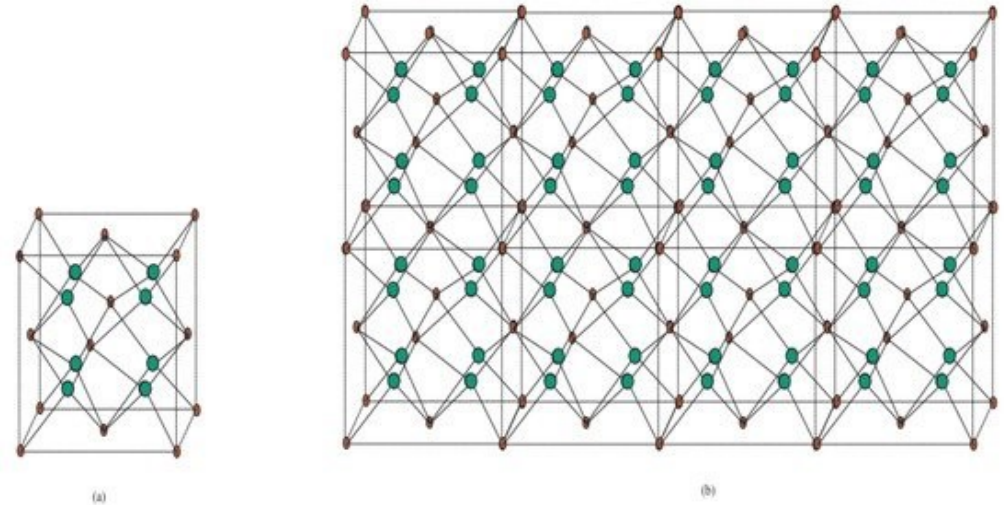


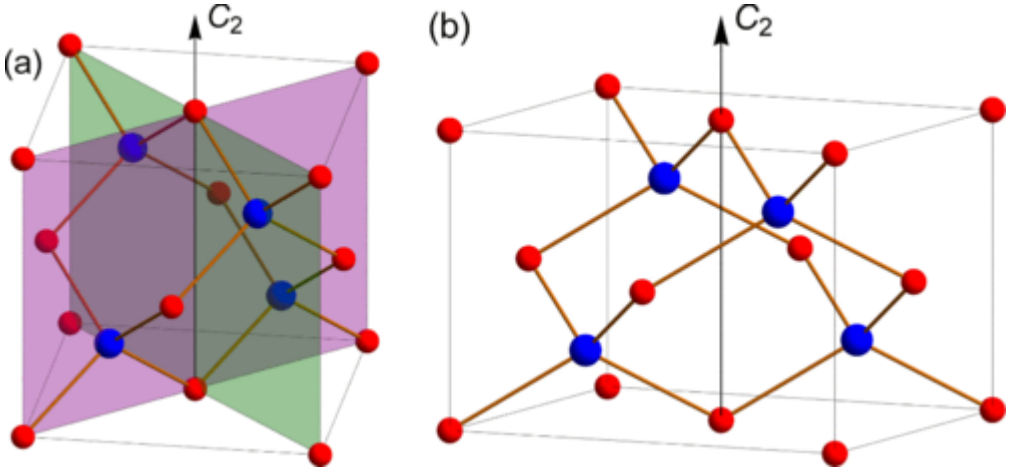
(c) (d) (e)

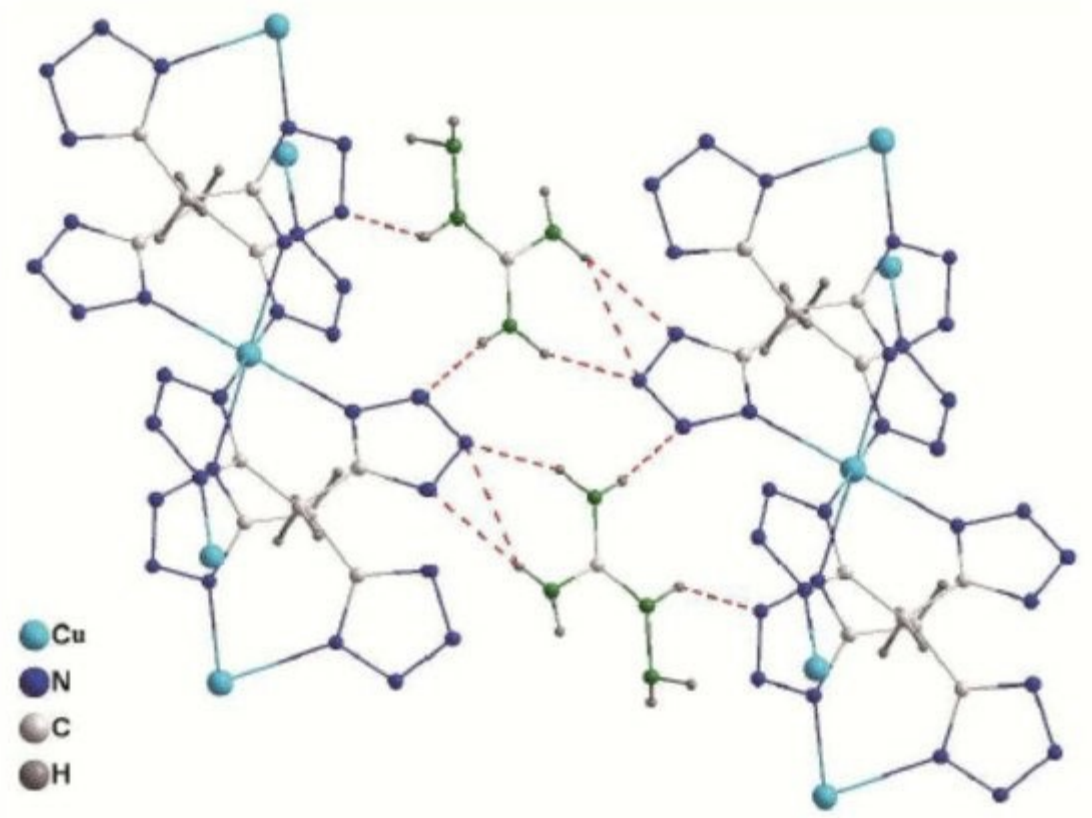


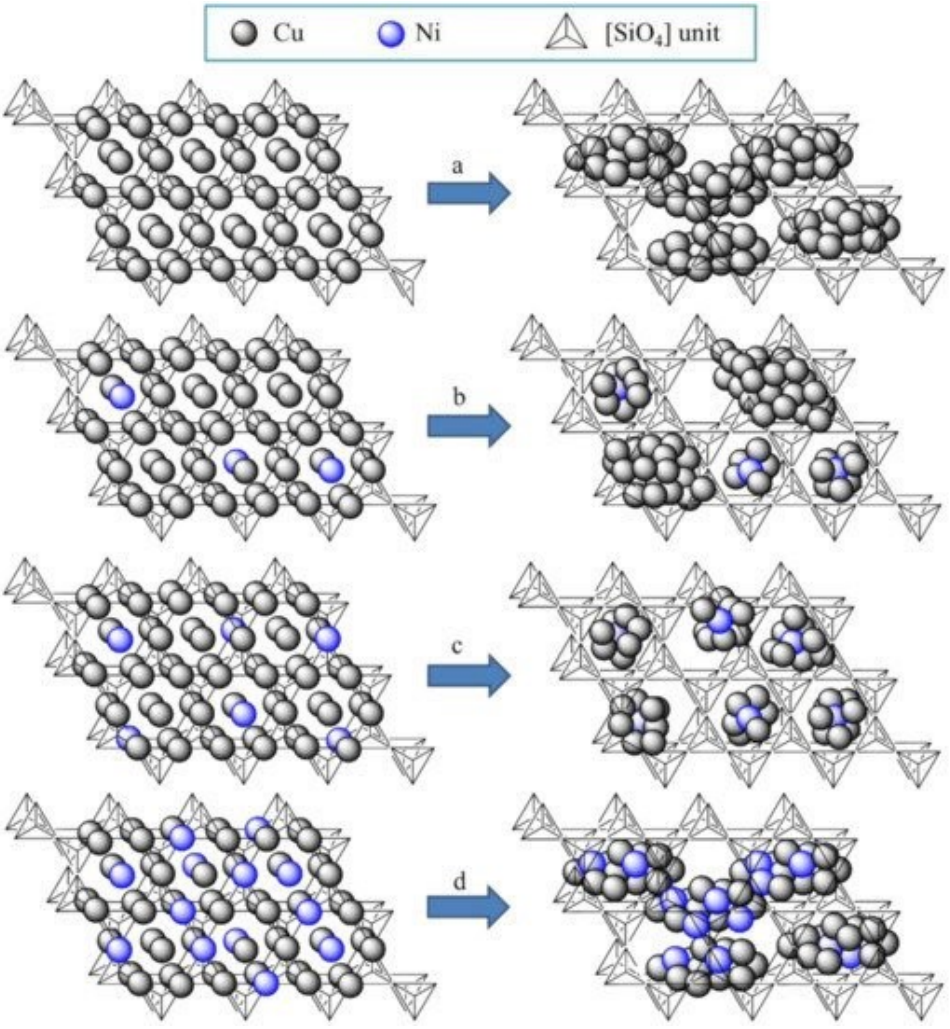
(0 *k l*) (*h* 0 *l*) (*h k* 0)

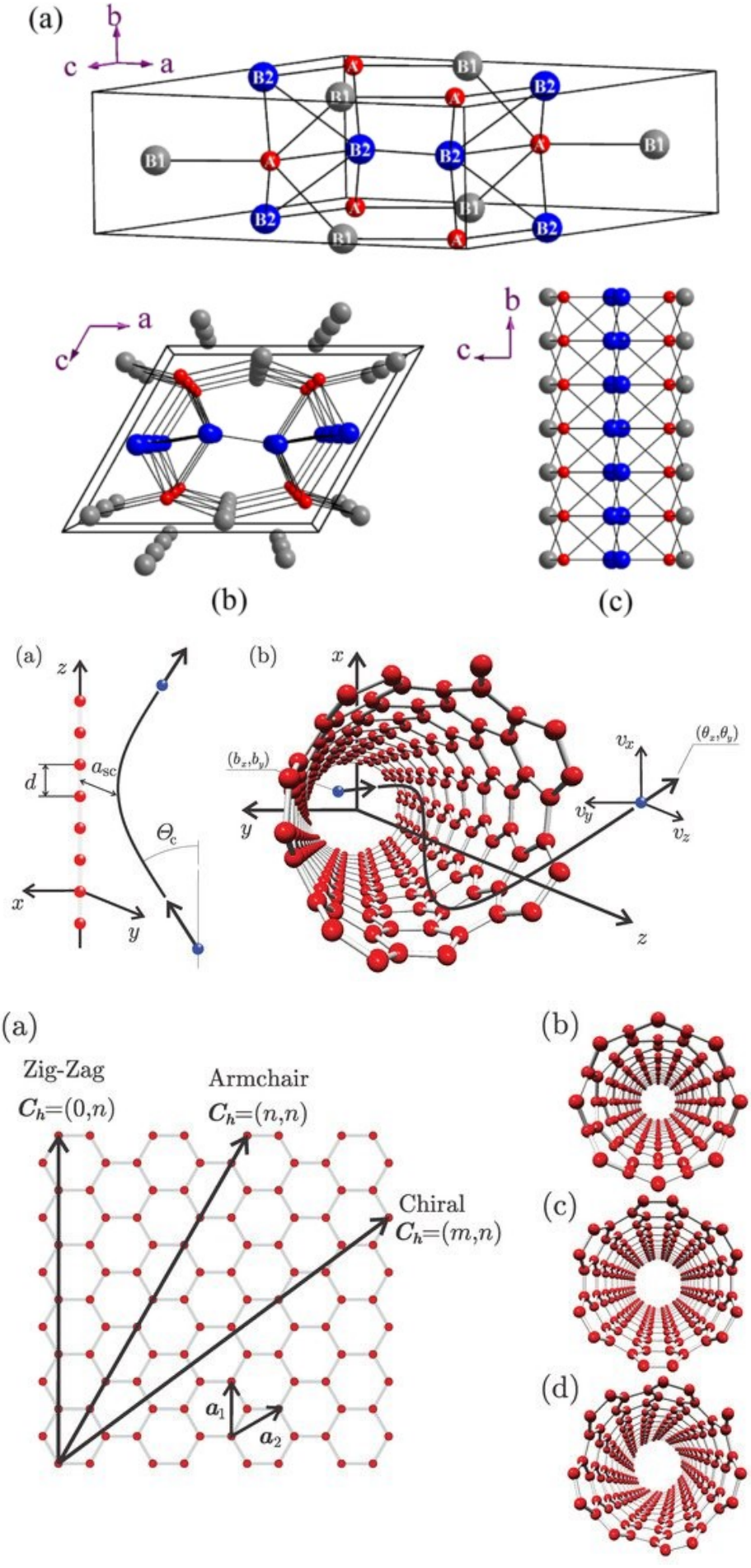


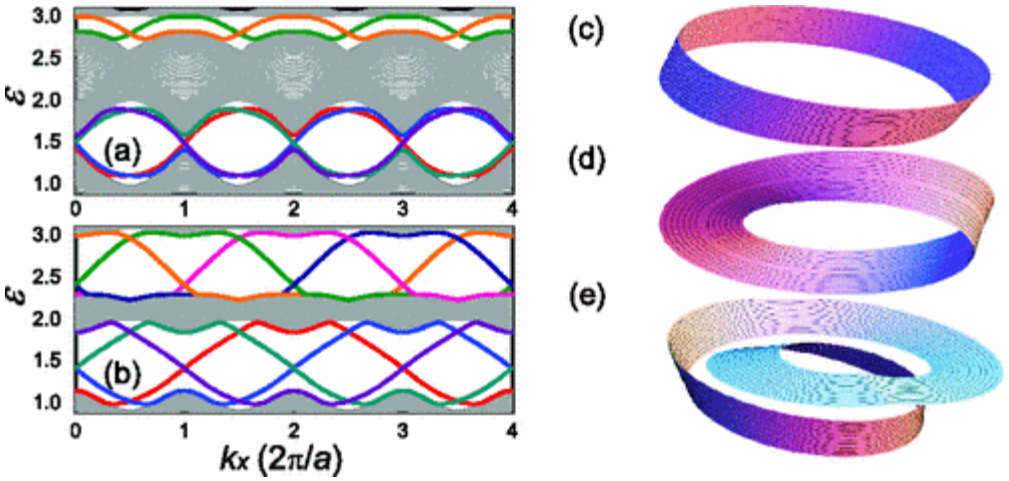

(a)
(b)

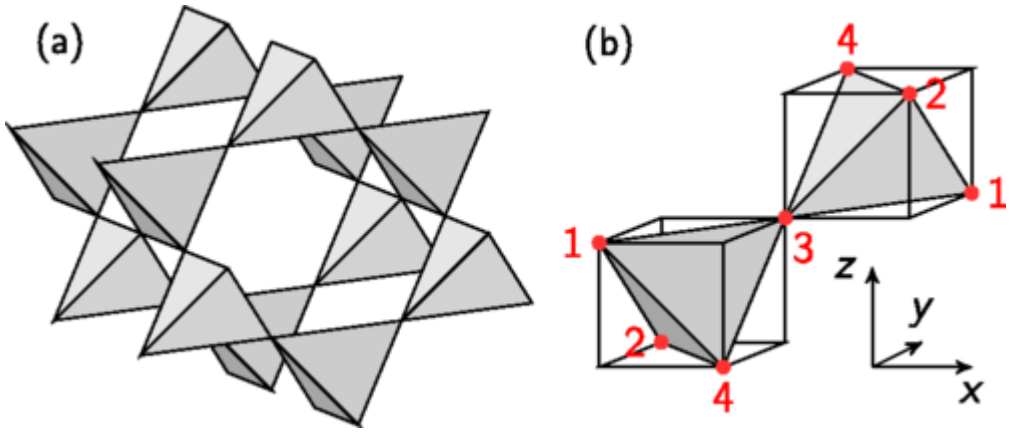

(a)
C_2
(b)
C_2

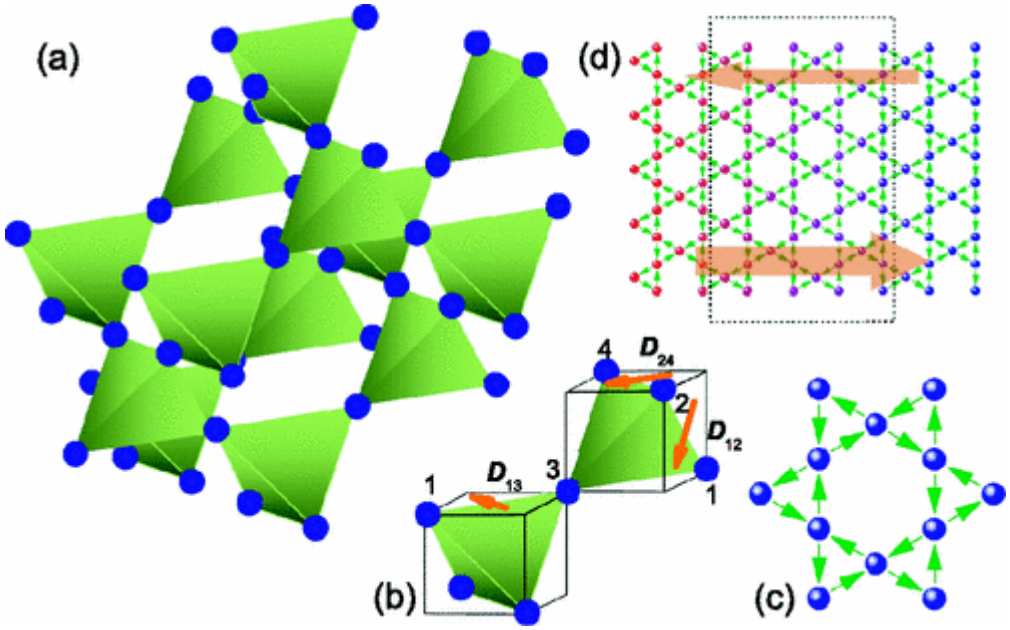

Cu
N
C
H

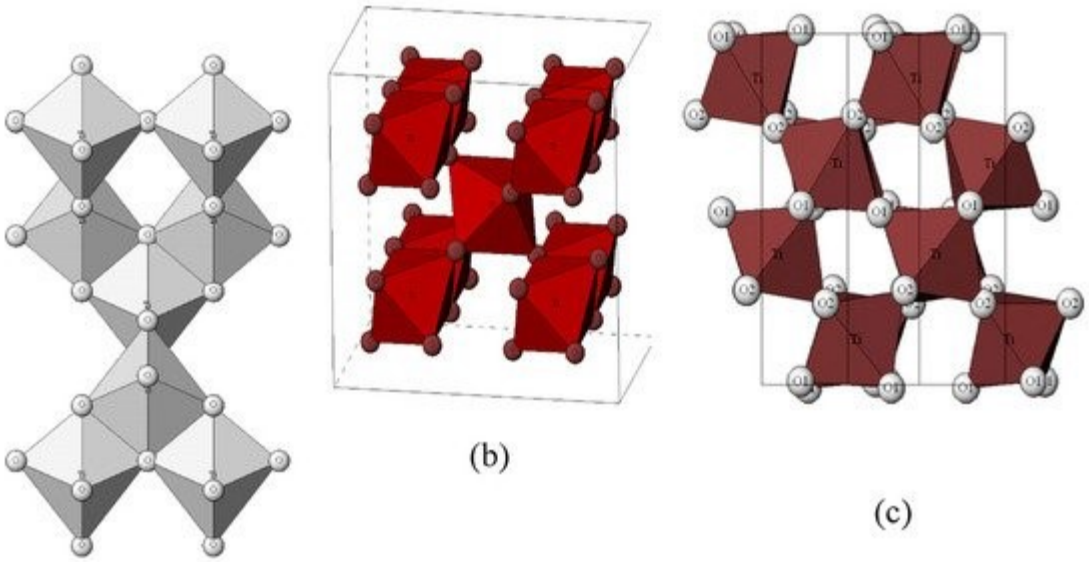

Cu
Ni
[SiO4] unit
a
b
c
d

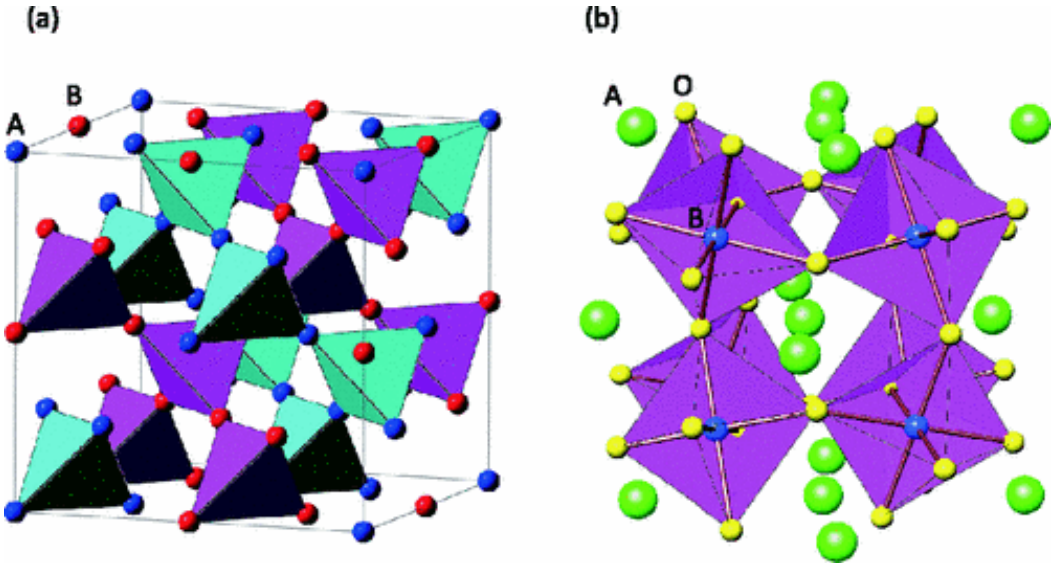

(a)
b
c
a
B2
A
B1
(b)
(c)
(a)
z
a_{sc}
d
Θ_c
x
y
(b)
x
(b_x,b_y)
y
v_x
(θ_x,θ_y)
v_y
v_z
z
(a)
Zig-Zag
C_h=(0,n)
Armchair
C_h=(n,n)
Chiral
C_h=(m,n)
a_1
a_2
(b)
(c)
(d)

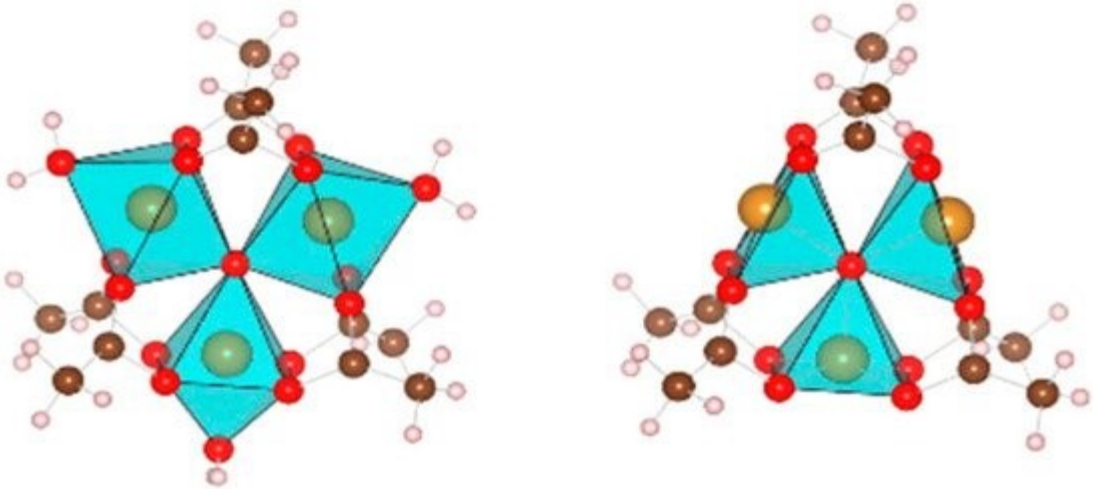

3.0
2.5
2.0
1.5
1.0
ε
(a)
0
1
2
3
4
(b)
kx (2π/a)
(c)
(d)
(e)

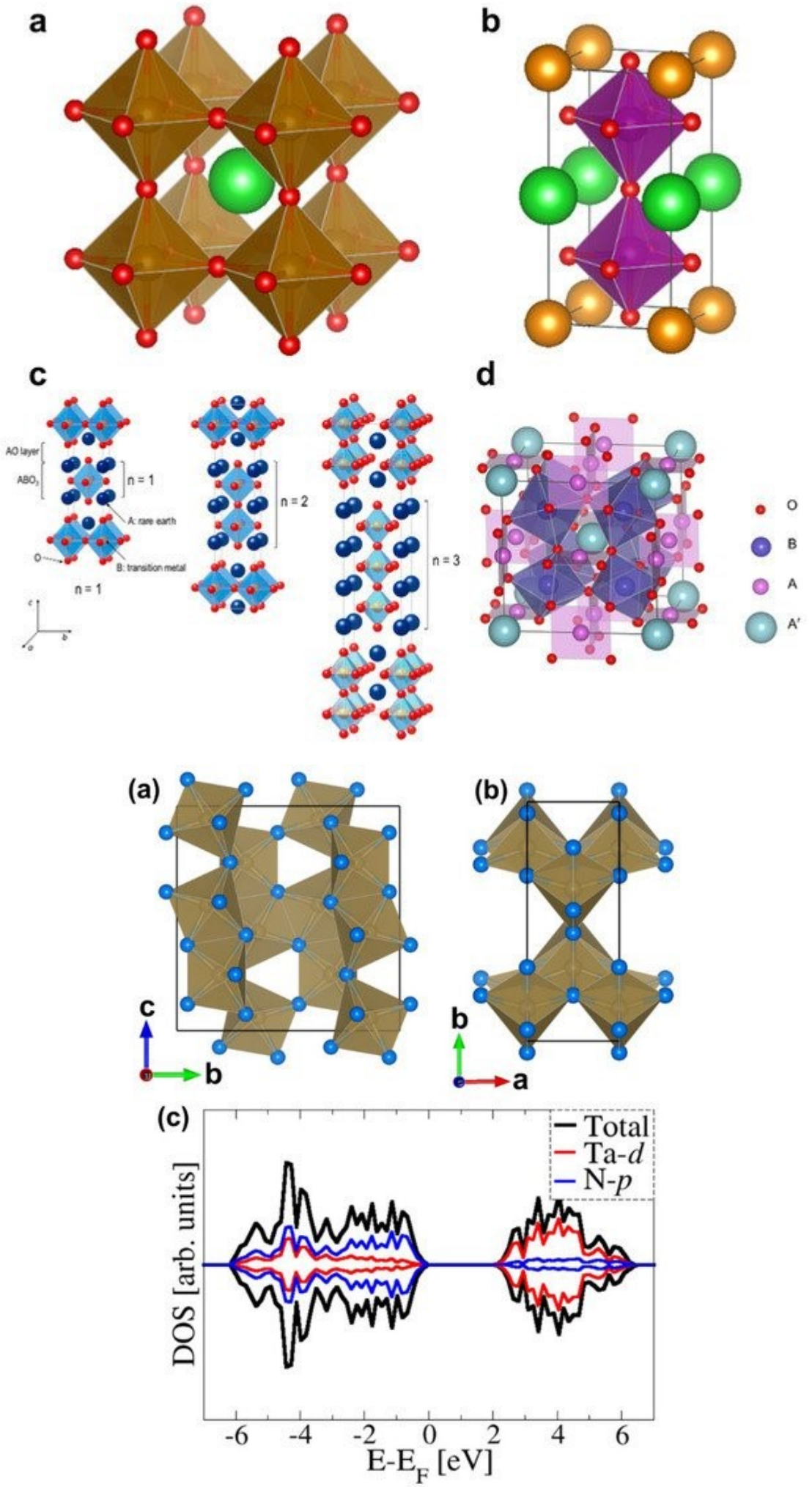

(a)
(b)
4
2
1
1
3
2
4
z
y
x

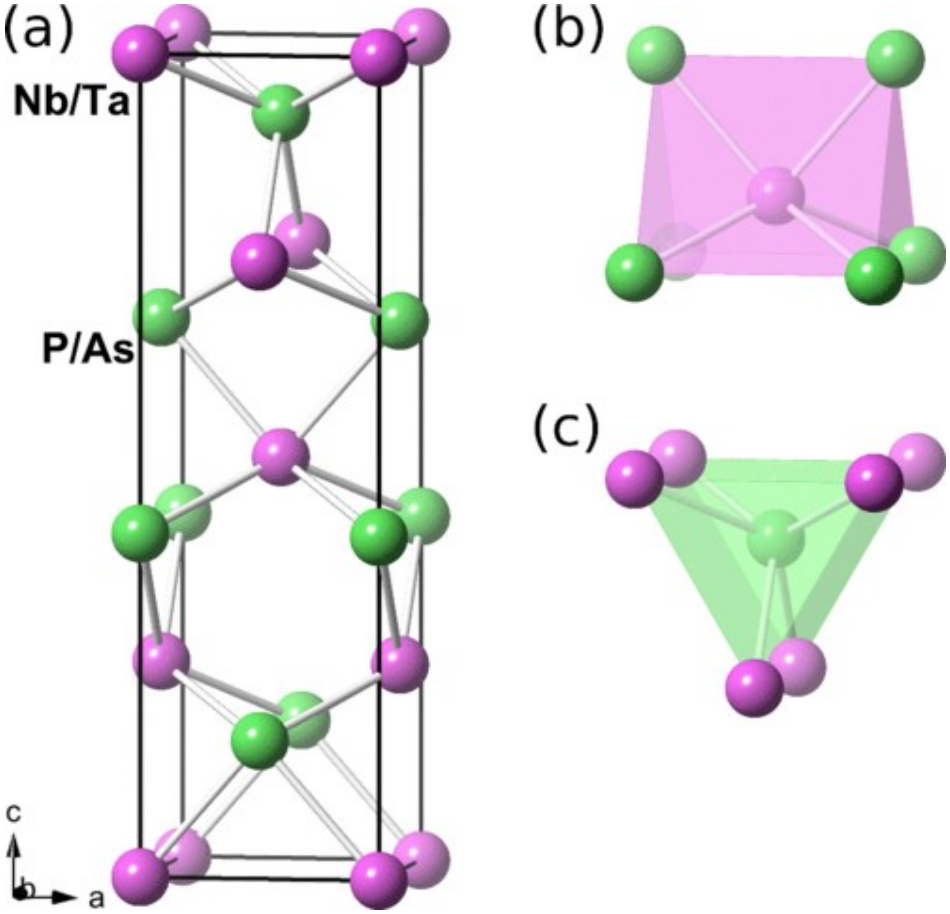

(a)
(d)
4
D24
2
D12
1
D13
3
1
(b)
(c)

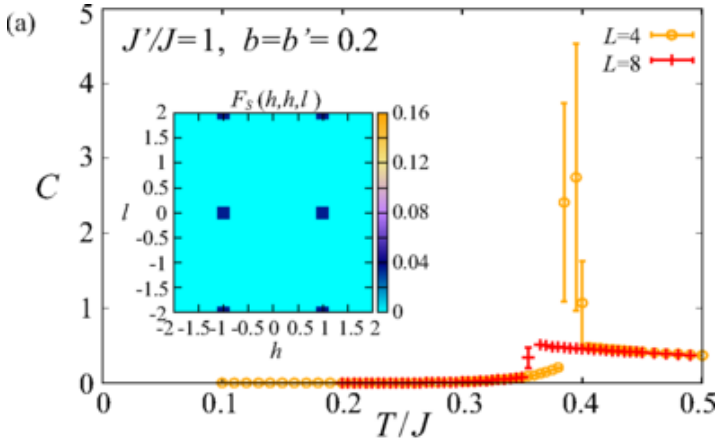

(a)
(b)
(c)

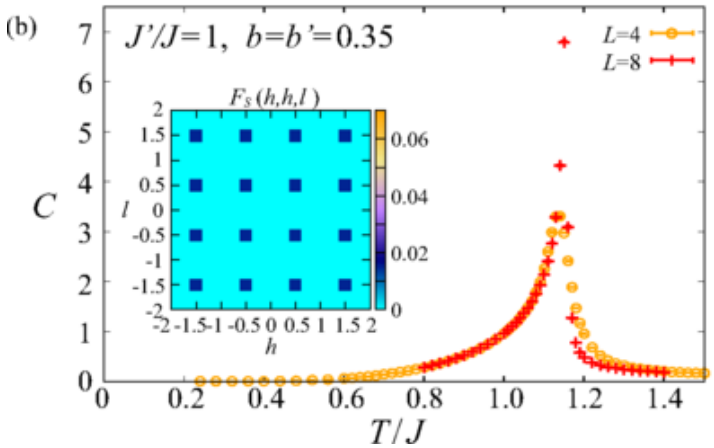

(a)
(b)
A
B
A
O
B

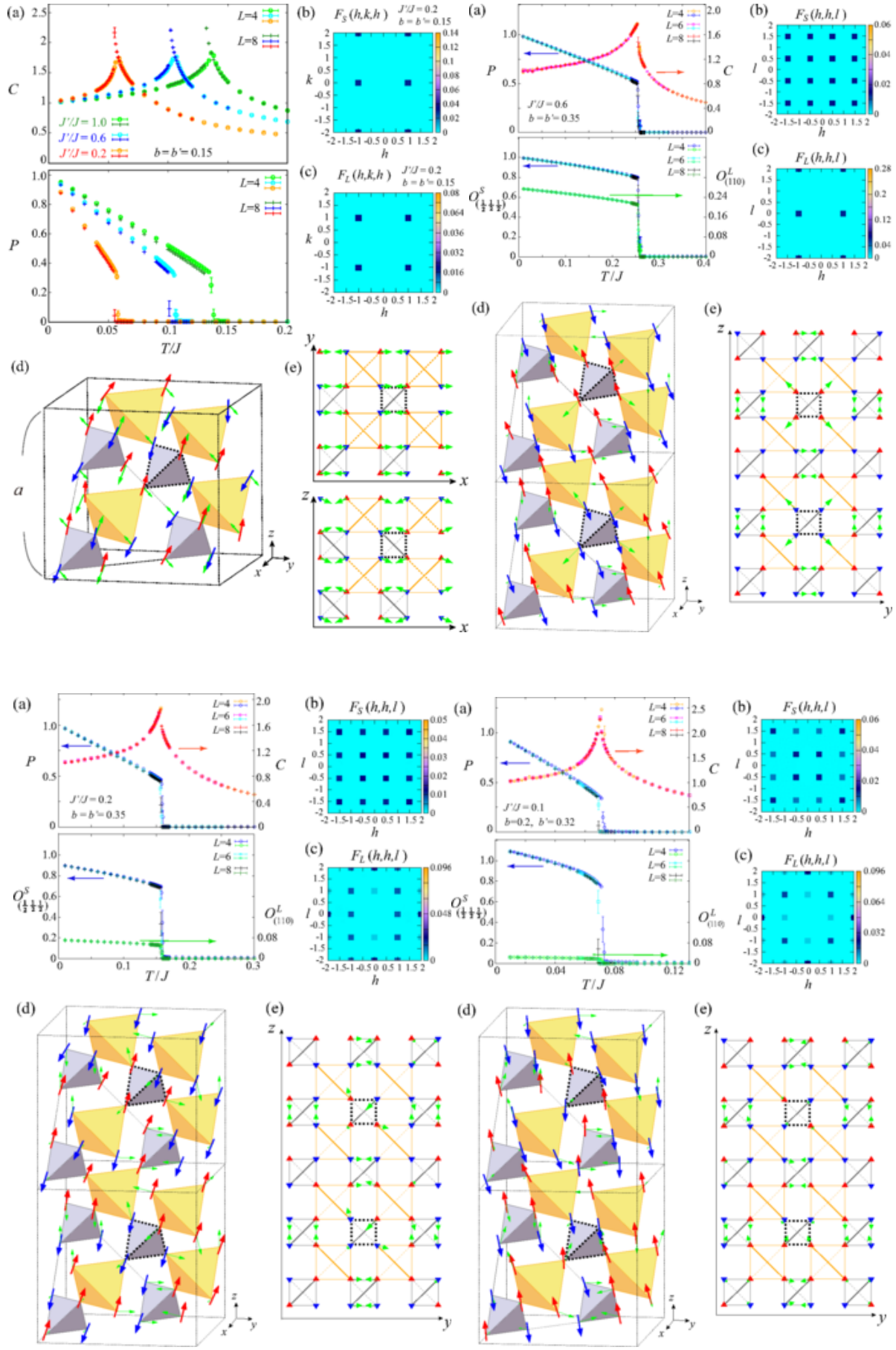


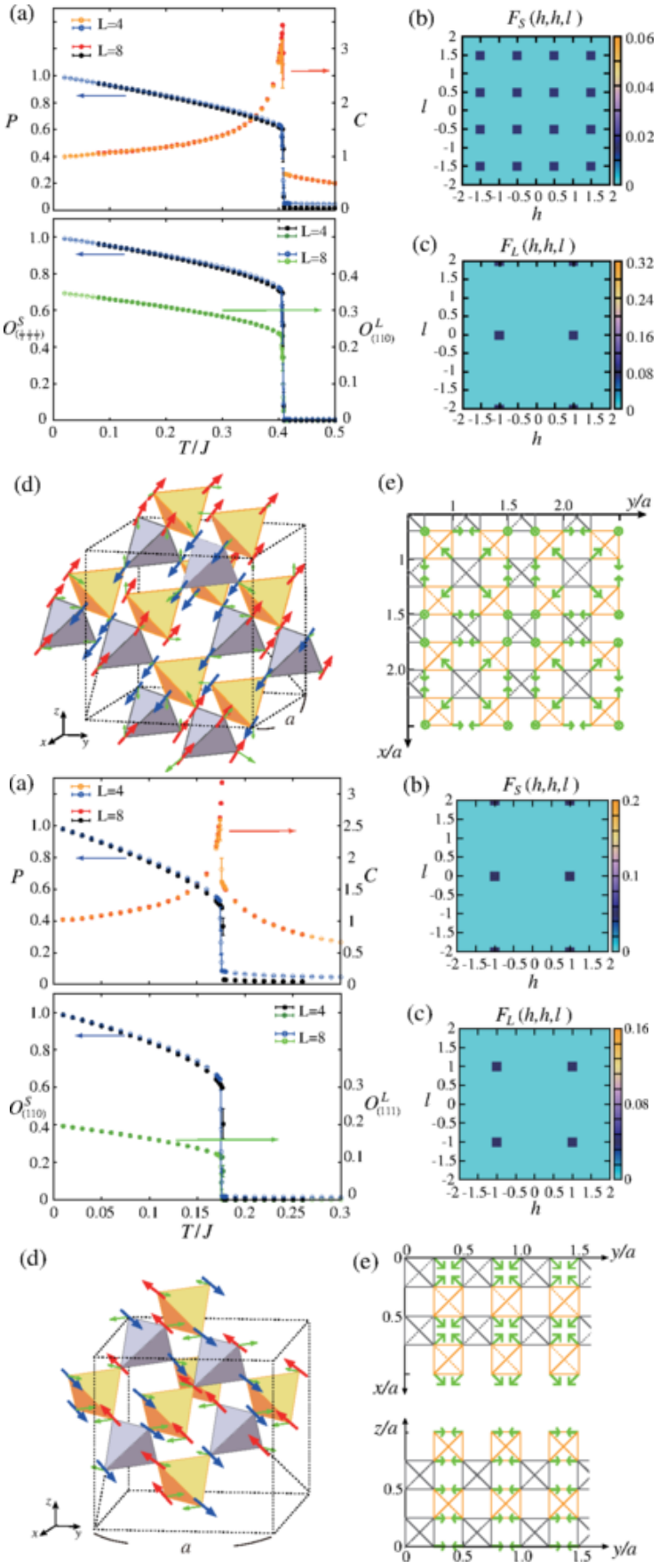

a
b
c
d
AO layer
ABO3
n = 1
A: rare earth
O
B: transition metal
n = 1
n = 2
n = 3
O
B
A
A'
(a)
(b)
c
b
b
a
(c)
Total
Ta-d
N-p
DOS [arb. units]
-6
-4
-2
0
2
4
6
E-E_F [eV]

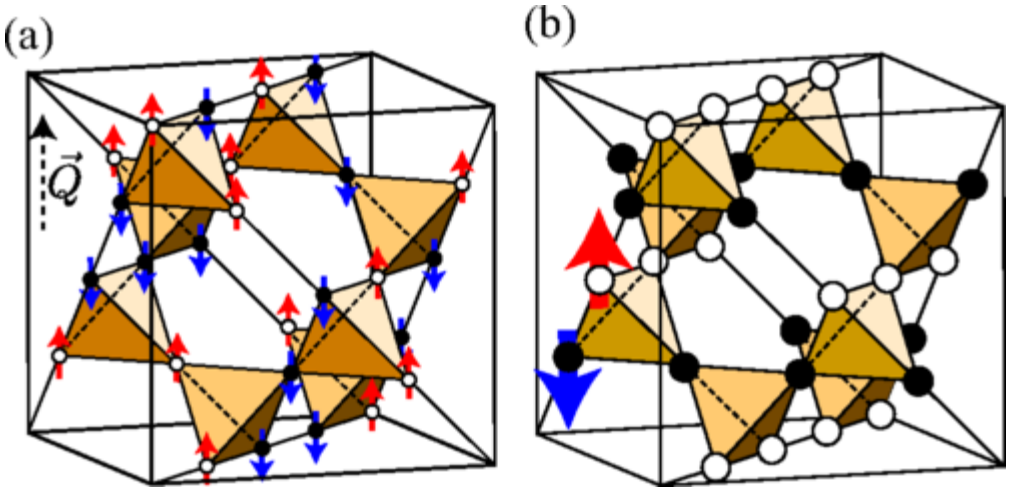

(a)
Nb/Ta
P/As
c
b
a
(b)
(c)

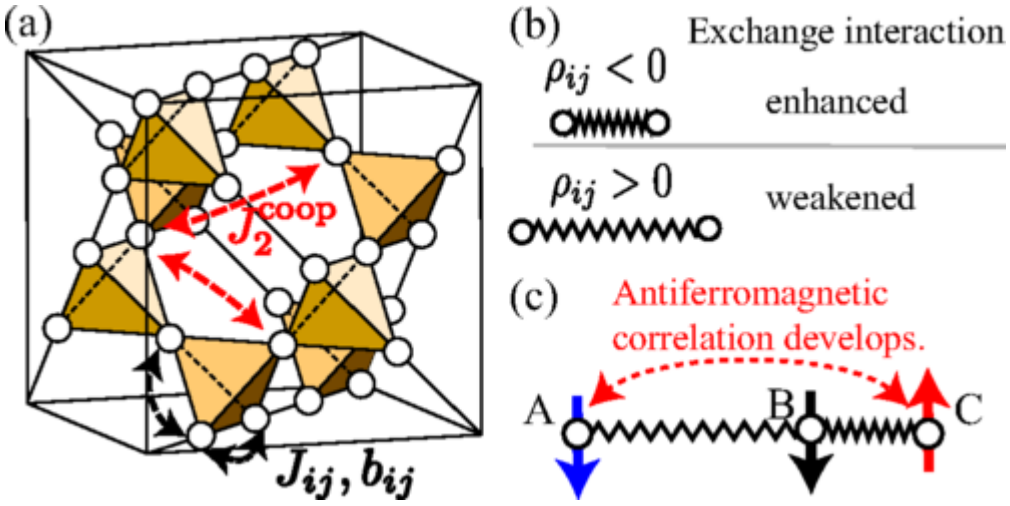

(a)
J'/J=1, b=b'=0.2
L=4
L=8
C
T/J
F_S(h,h,l)
h
l

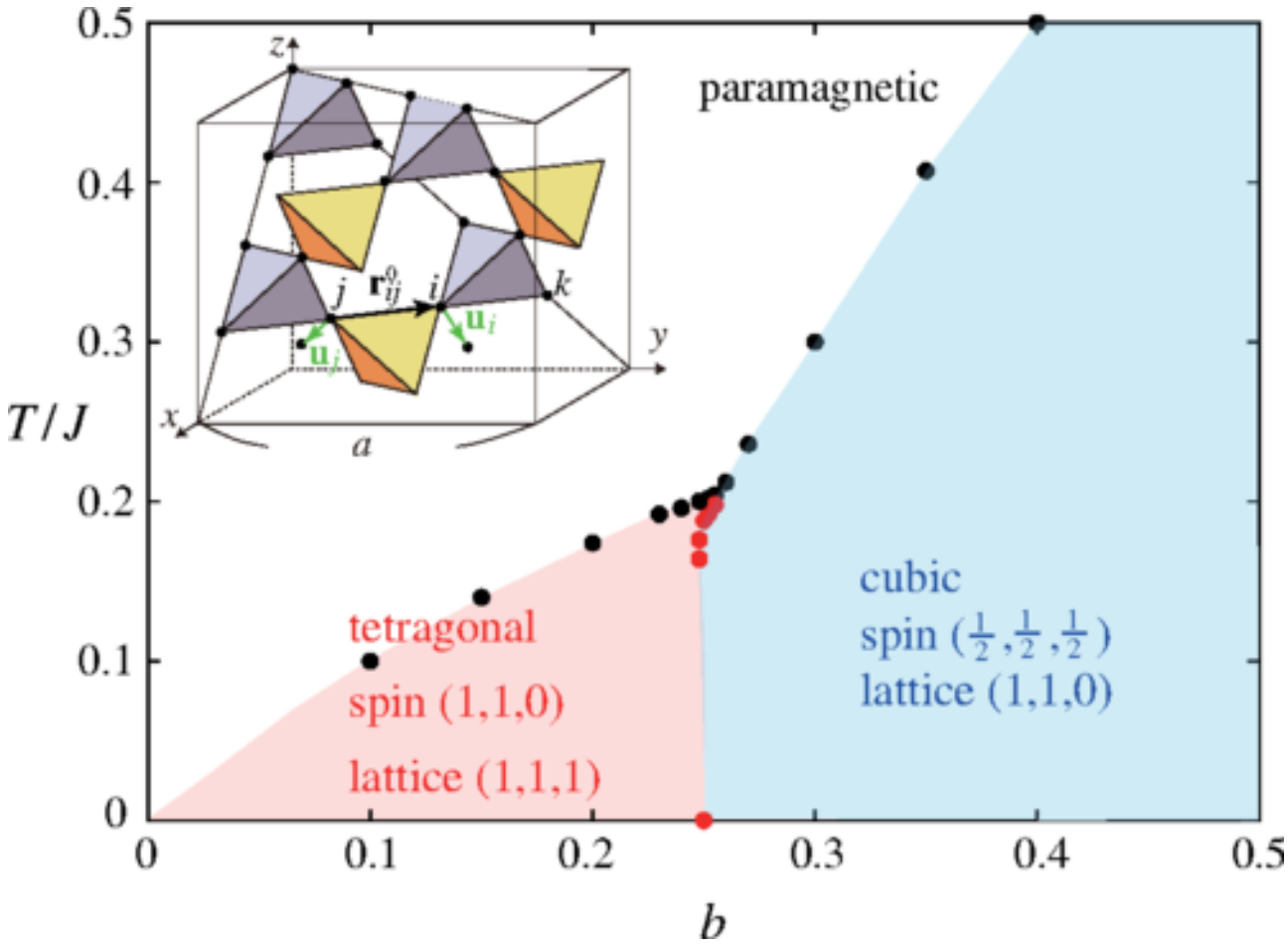

(b)
J'/J=1, b=b'=0.35
L=4
L=8
C
T/J
F_S(h,h,l)
h
l

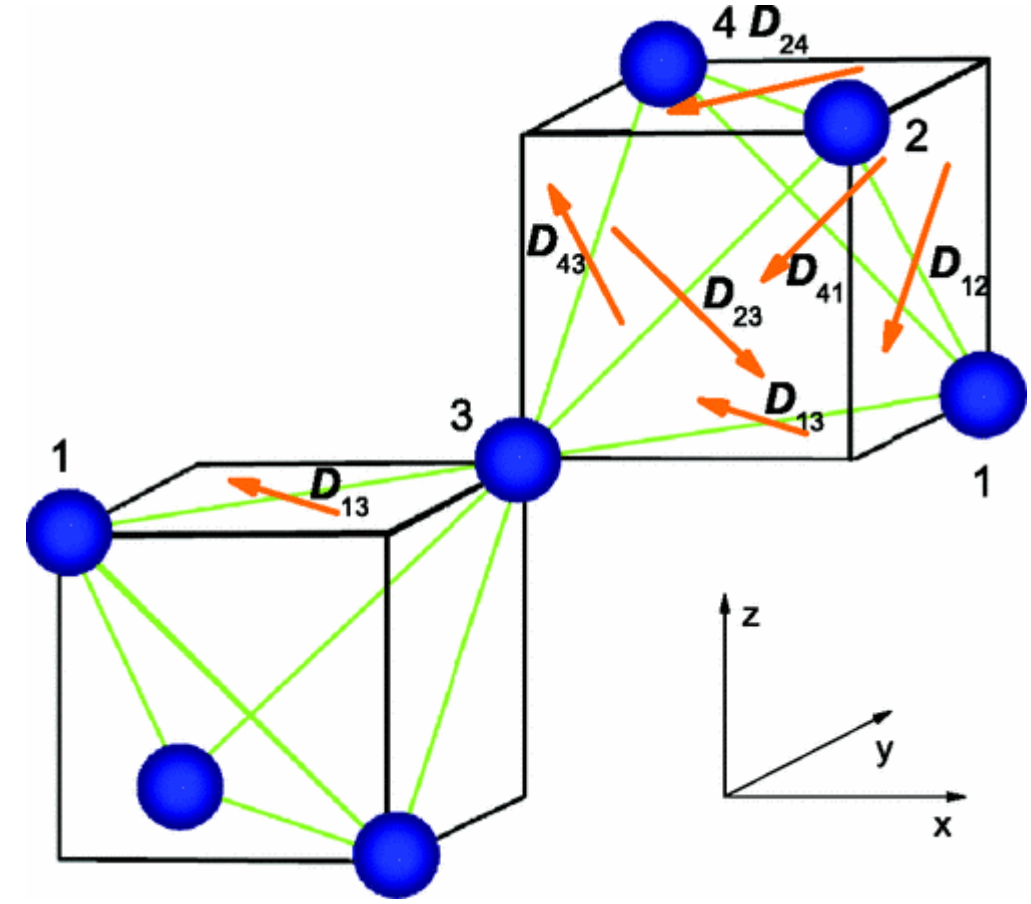

(a)
(b)
(c)
(d)
(e)
C
P
T/J
L=4
L=6
L=8
J'/J = 1.0
J'/J = 0.6
J'/J = 0.2
b = b' = 0.15
J'/J = 0.2
b = b' = 0.35
J'/J = 0.1
b=0.2, b'=0.32
F_S(h,k,h)
F_L(h,k,h)
F_S(h,h,l)
F_L(h,h,l)
h
k
l
a
x
y
z

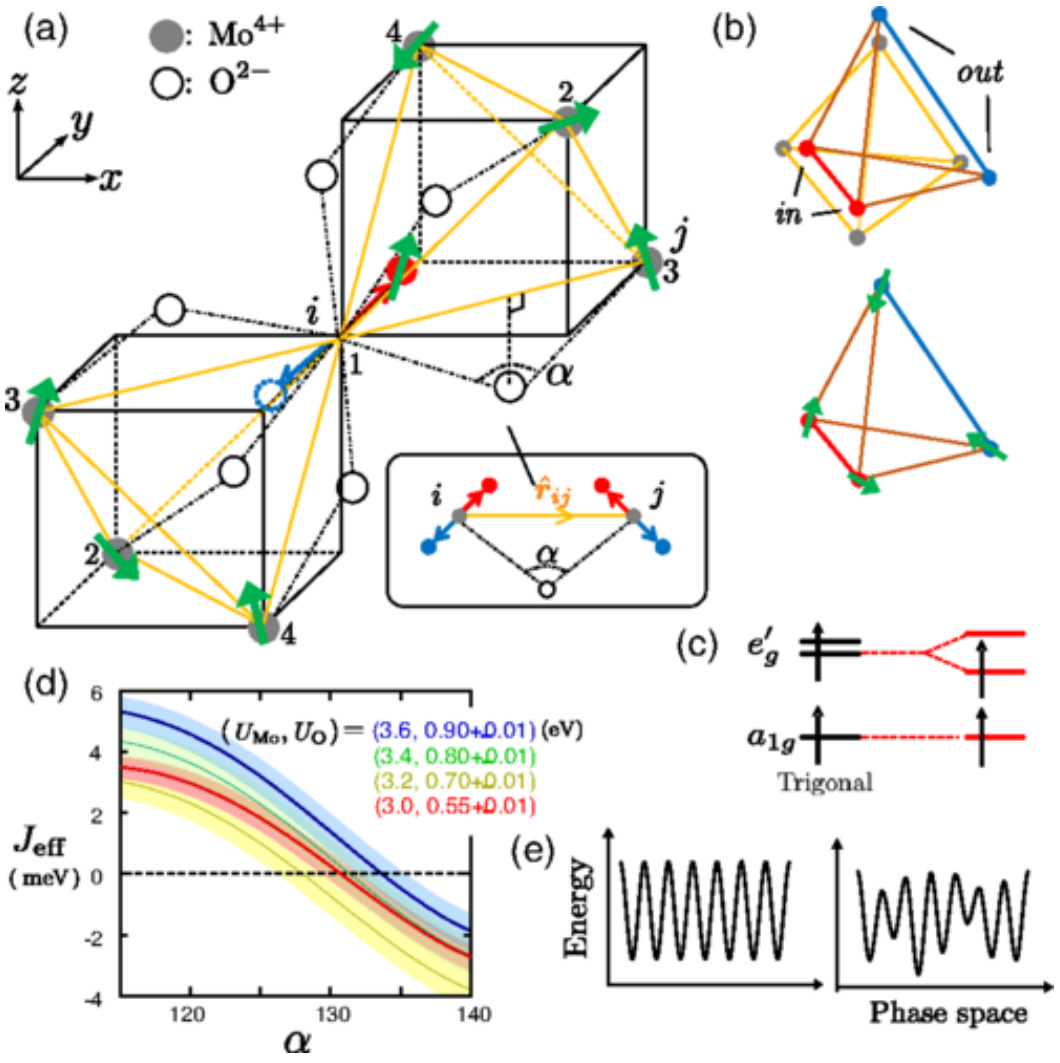

(a)
L=4
L=8
P
C
$O^S_{(\frac{1}{2}\frac{1}{2}\frac{1}{2})}$
$O^L_{(110)}$
T/J
(b)
$F_S(h,h,l)$
(c)
$F_L(h,h,l)$
h
l
(d)
a
(e)
y/a
x/a
$O^S_{(110)}$
$O^L_{(111)}$
z/a

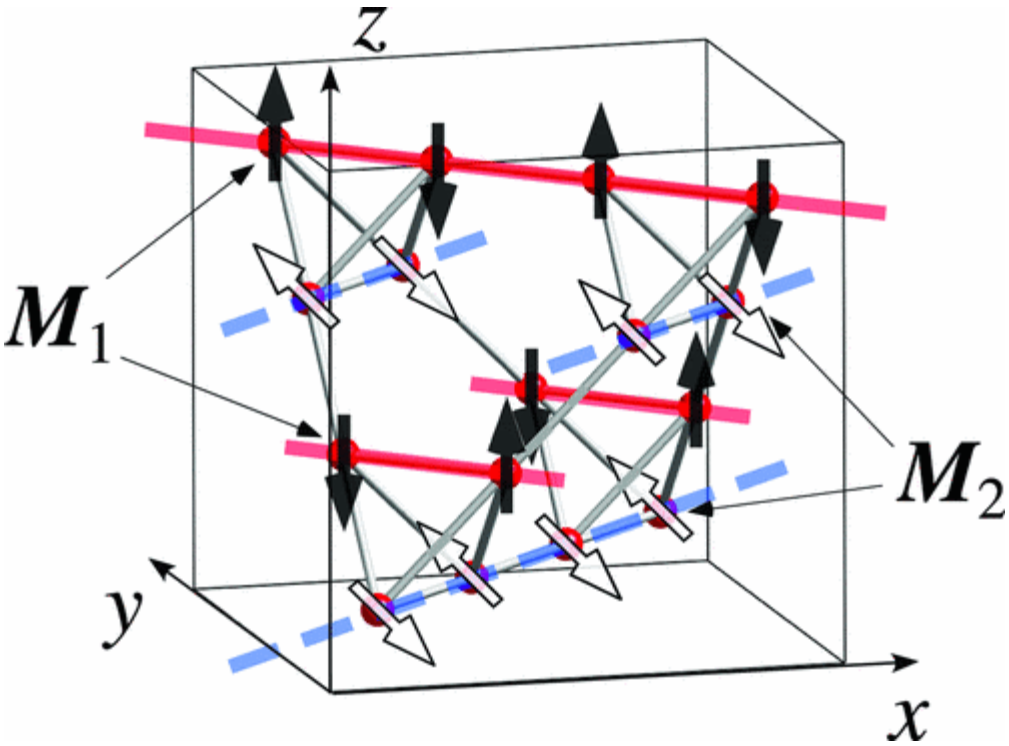

(a)
(b)
$\vec{Q}$


(a)
J_2^{coop}
J_{ij}, b_{ij}
(b)
Exchange interaction
$\rho_{ij} < 0$
enhanced
$\rho_{ij} > 0$
weakened
(c)
Antiferromagnetic
correlation develops.
A
B
C

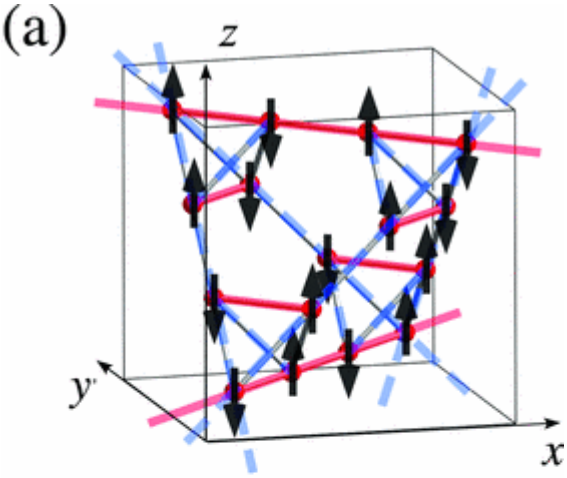

paramagnetic
tetragonal
spin (1,1,0)
lattice (1,1,1)
cubic
spin $(\frac{1}{2},\frac{1}{2},\frac{1}{2})$
lattice (1,1,0)
T / J
b
0
0.1
0.2
0.3
0.4
0.5
z
y
x
a
j
i
k
$\mathbf{r}_{ij}^{0}$
$\mathbf{u}_i$
$\mathbf{u}_j$


4 D24
2
D43
D41
D12
D23
D13
3
1
1
D13
z
y
x

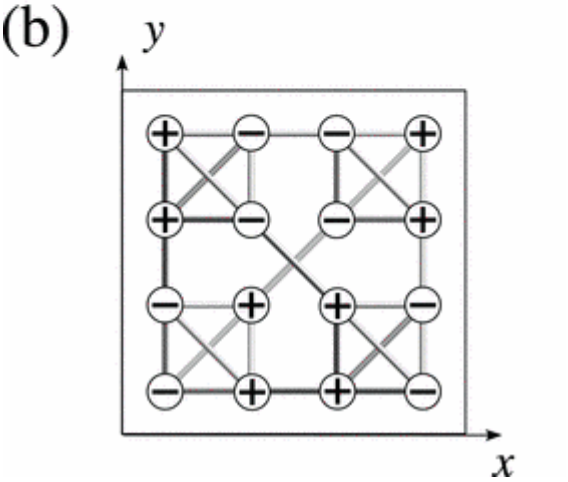

(a)
: Mo4+
: O2−
z
y
x
4
2
j
3
i
1
α
3
2
4
i
r̂ij
j
α
(b)
out
in
(c)
e′g
a1g
Trigonal
(d)
(UMo, UO) = (3.6, 0.90+0.01) (eV)
(3.4, 0.80+0.01)
(3.2, 0.70+0.01)
(3.0, 0.55+0.01)
Jeff
(meV)
6
4
2
0
-2
-4
120
130
140
α
(e)
Energy
Phase space

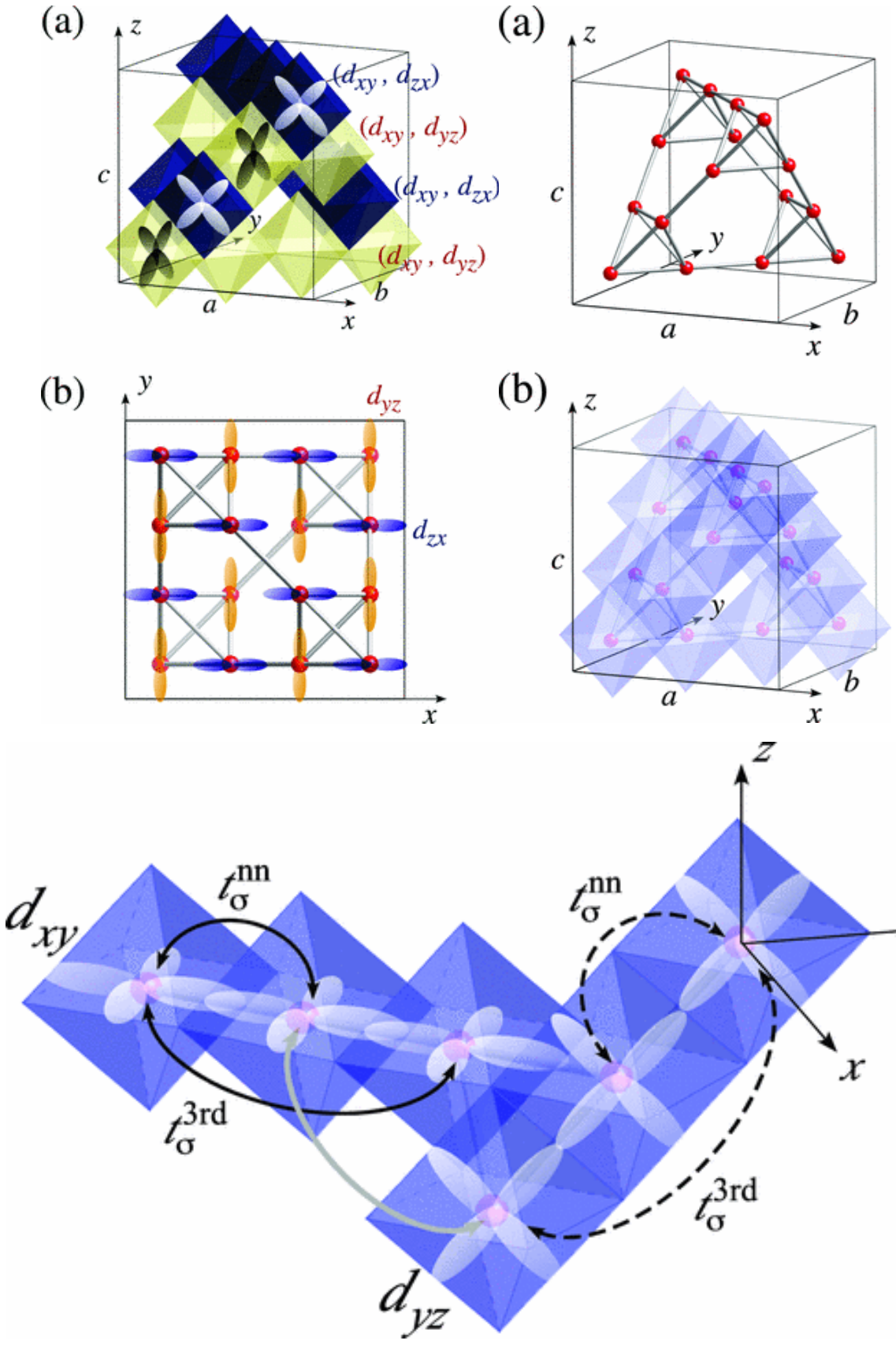


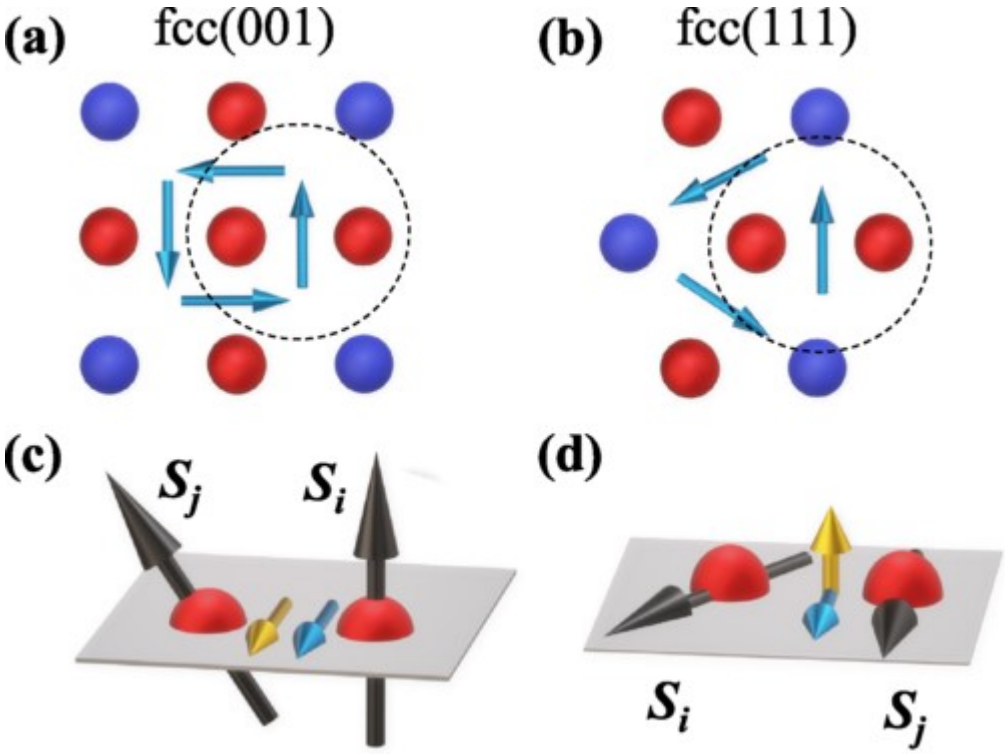
(a)

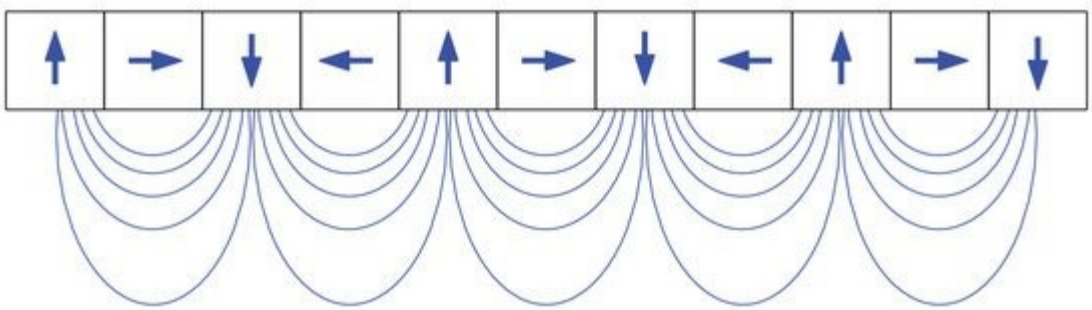


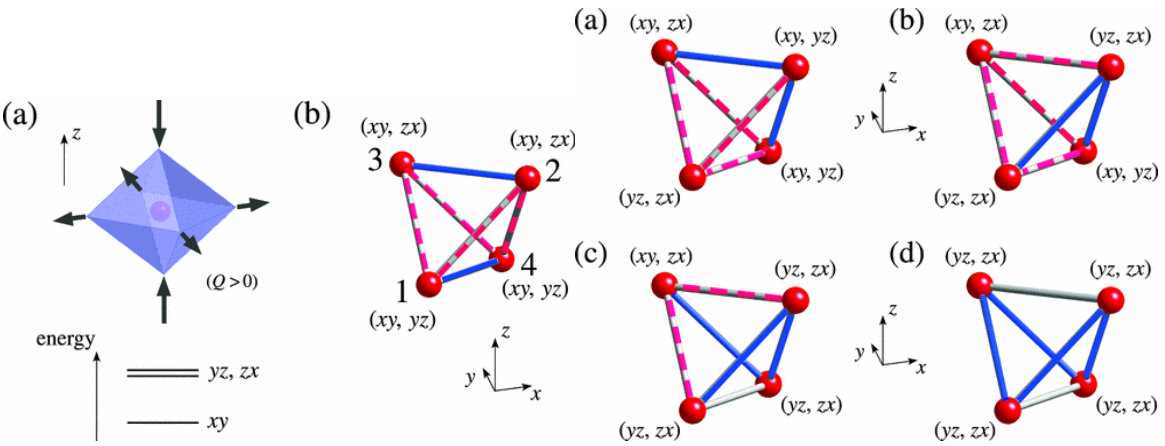
(b)

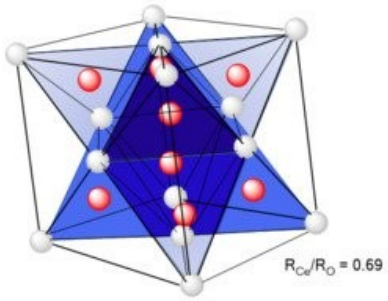



(a)
z
c
y
a
x
b
(d_{xy}, d_{zx})
(d_{xy}, d_{yz})
(d_{xy}, d_{zx})
(d_{xy}, d_{yz})
(a)
z
c
y
a
x
b
(b)
y
d_{yz}
d_{zx}
x
(b)
z
c
y
a
x
b
z
d_{xy}
t_σ^{nn}
t_σ^{nn}
y
x
t_σ^{3rd}
t_σ^{3rd}
d_{yz}

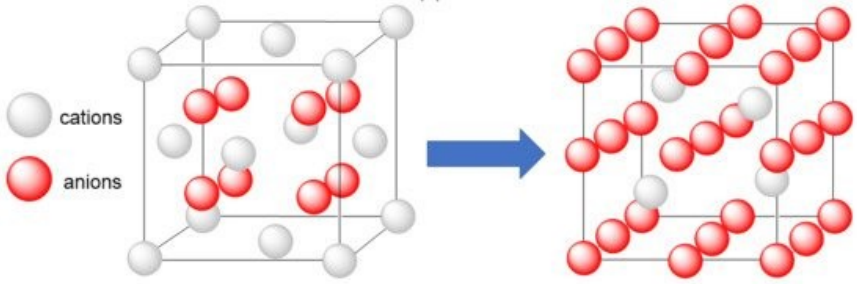

(a)
fcc(001)
(b)
fcc(111)
(c)
S_j
S_i
(d)
S_i
S_j



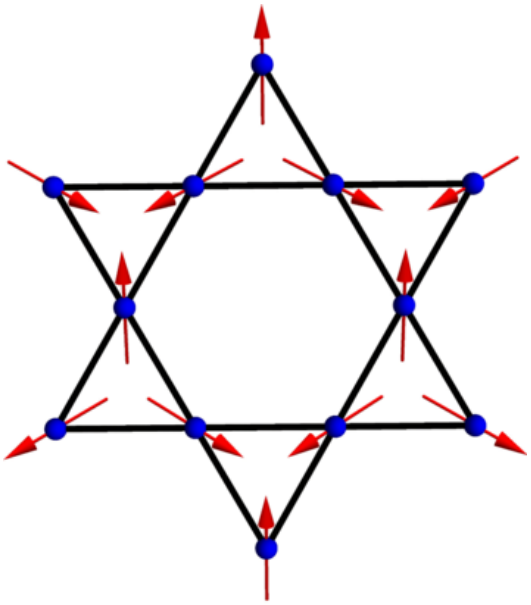

(a)
z
(Q > 0)
energy
yz, zx
xy
(b)
(xy, zx)
(xy, zx)
3
2
4
1
(xy, yz)
(xy, yz)
z
y
x
(a)
(xy, zx)
(xy, yz)
(yz, zx)
(xy, yz)
(b)
(xy, zx)
(yz, zx)
z
y
x
(yz, zx)
(xy, yz)
(c)
(xy, zx)
(yz, zx)
(yz, zx)
(yz, zx)
(d)
(yz, zx)
(yz, zx)
z
y
x
(yz, zx)
(yz, zx)



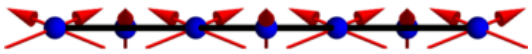
(a)



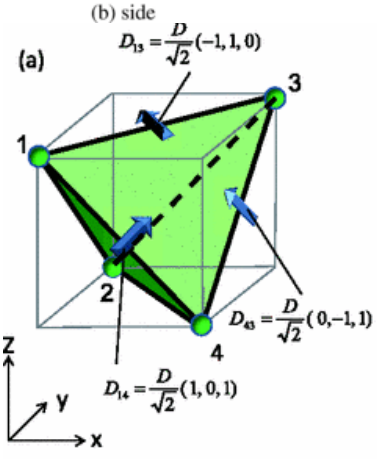
(b)

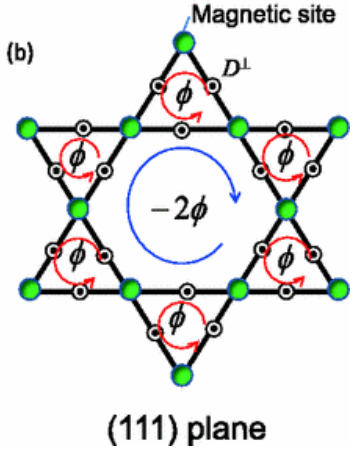


(a) top

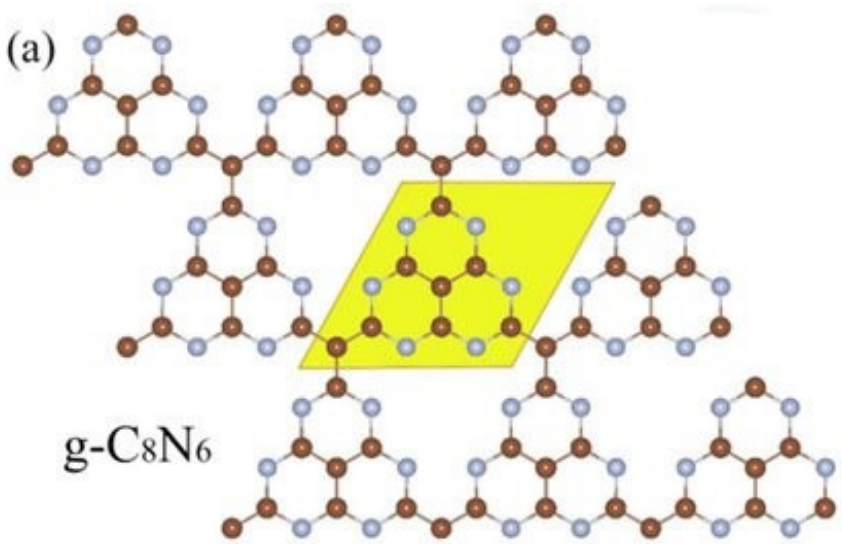


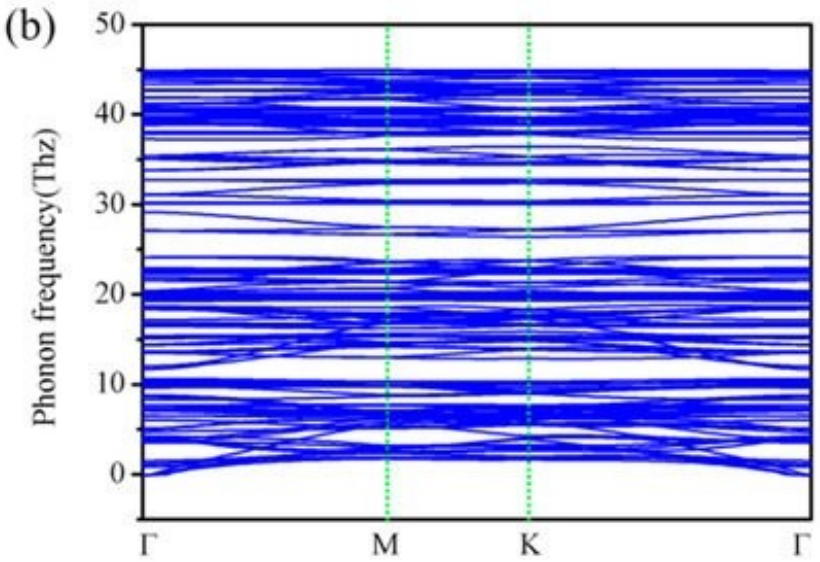
(b) side

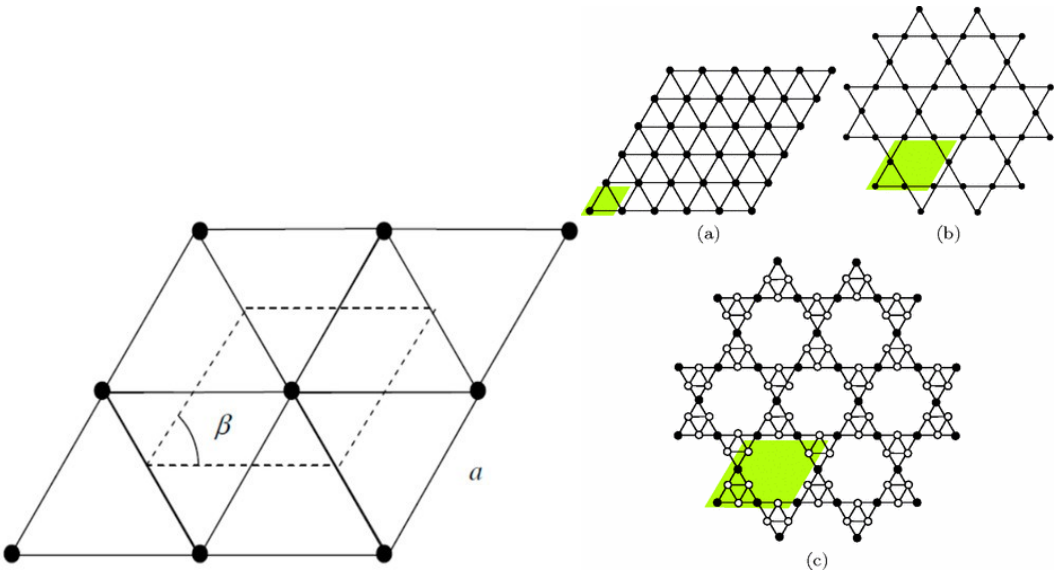


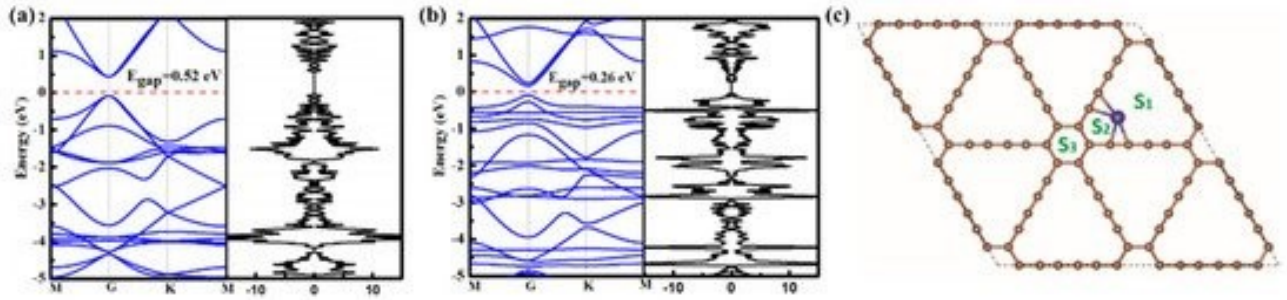


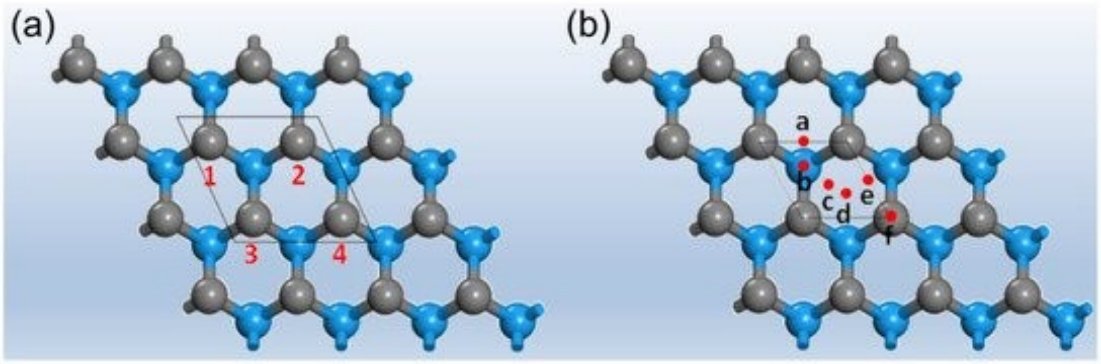
(111) plane

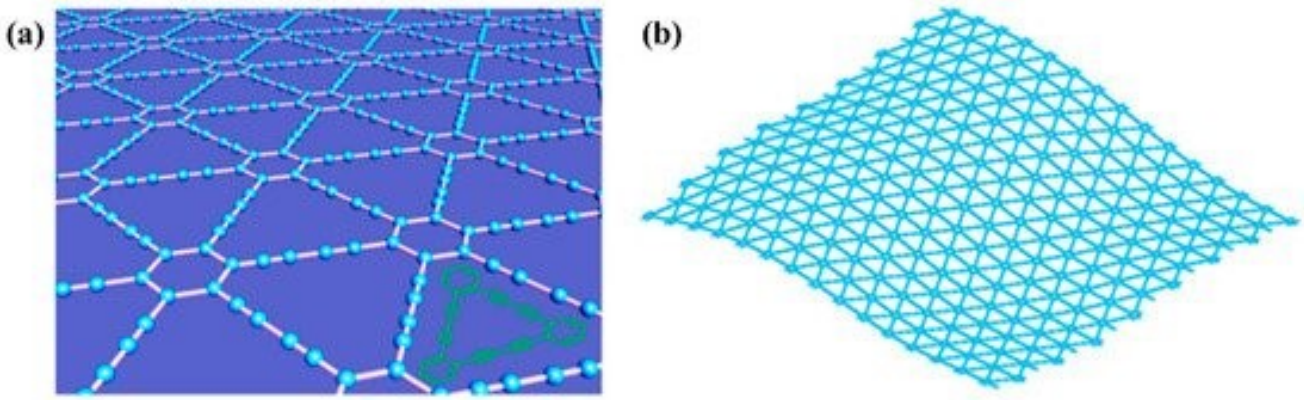

(a)
g-C8N6

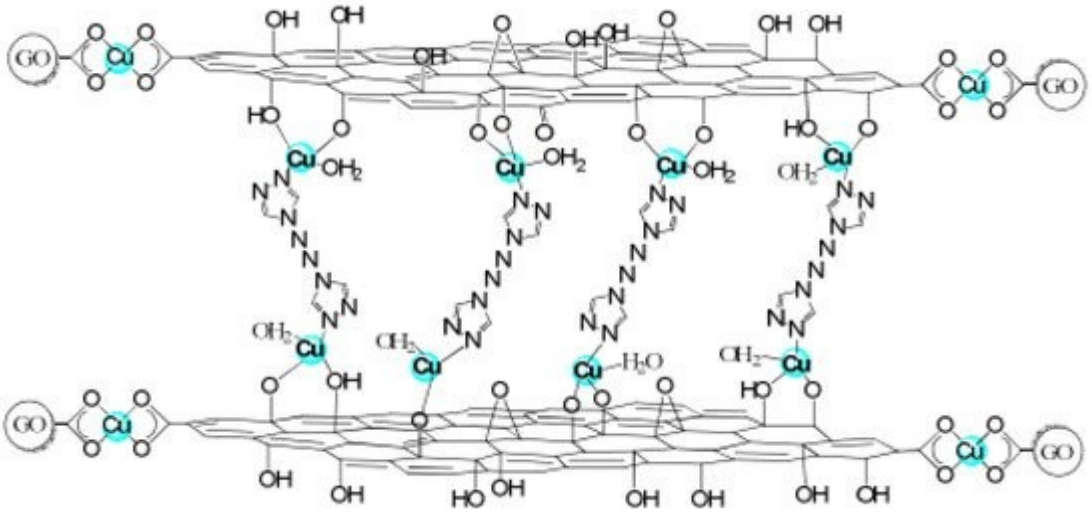

(b)
Phonon frequency(Thz)
50
40
30
20
10
0
Γ
M
K
Γ

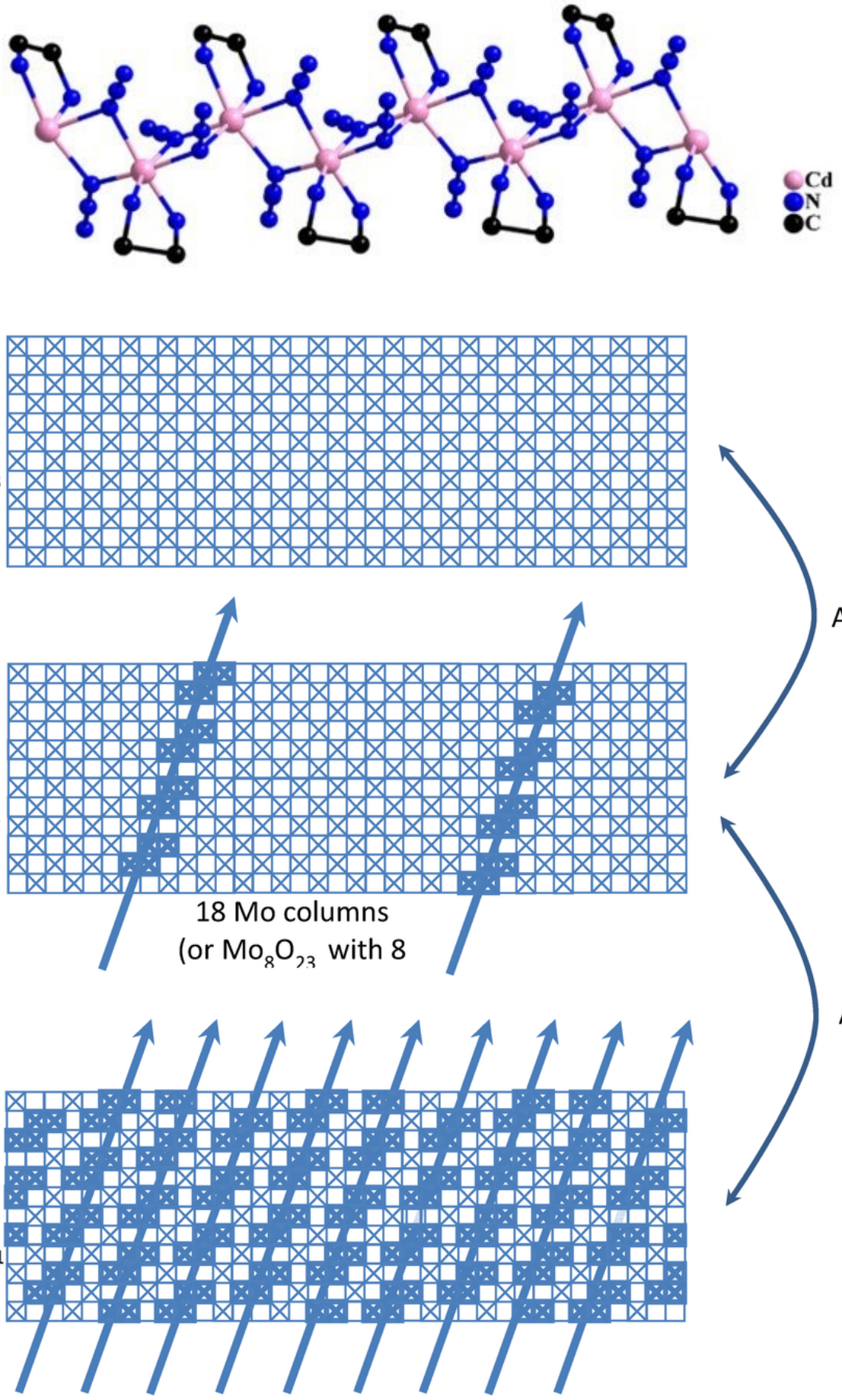

β
a
(a)
(b)
(c)

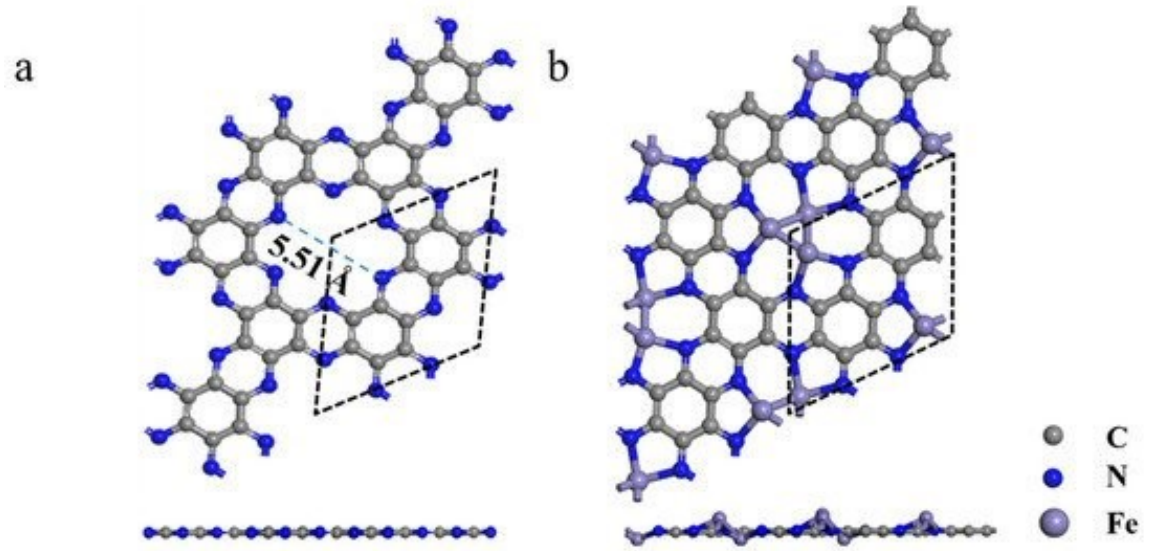

(a)
(b)
(c)
E_{gap}=0.52 eV
E_{gap}=0.26 eV
Energy (eV)
M G K M
-10 0 10
S1
S2
S3

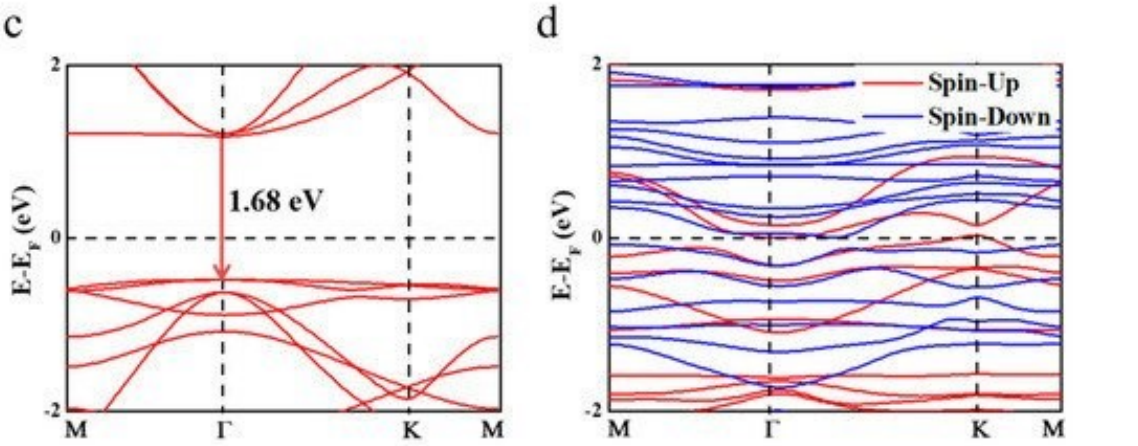

(a)
(b)
1
2
3
4
a
b
c
d
e
f

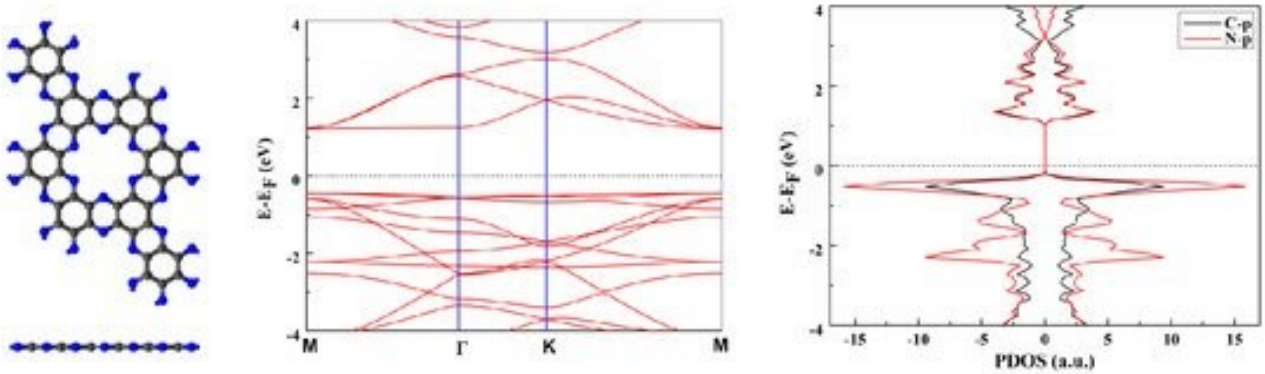

(a)
(b)


GO
Cu
OH
HO
OH_2
H_2O
N

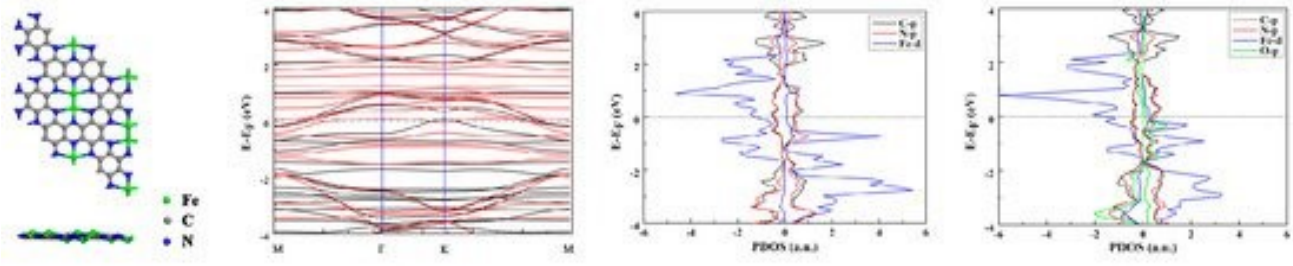

Cd
N
C
(a
MoO_3
Activation
(b
$Mo_{18}O_{52}$
18 Mo columns
(or Mo_8O_{23} with 8
Aging
(c
Mo_4O_{11}


a
b
5.51 Å
C
N
Fe

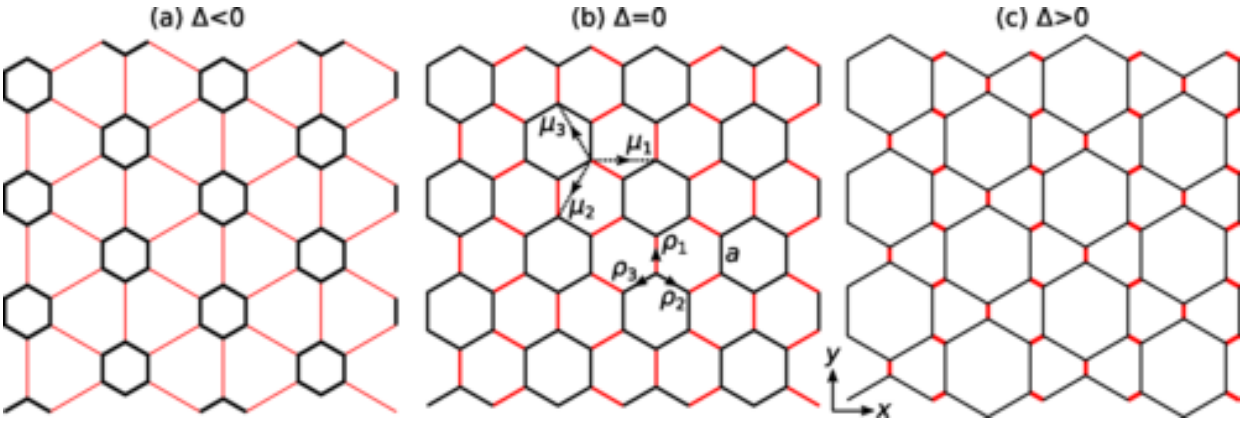

c
d
1.68 eV
E-E_F (eV)
M
Γ
K
M
Spin-Up
Spin-Down

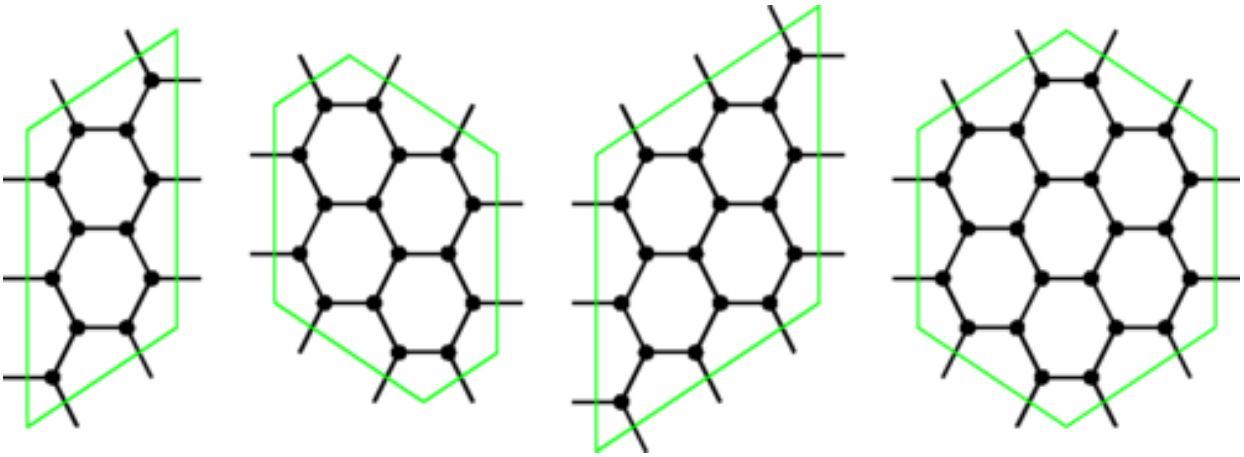

E-E_F (eV)
M
Γ
K
M
C-p
N-p
PDOS (a.u.)

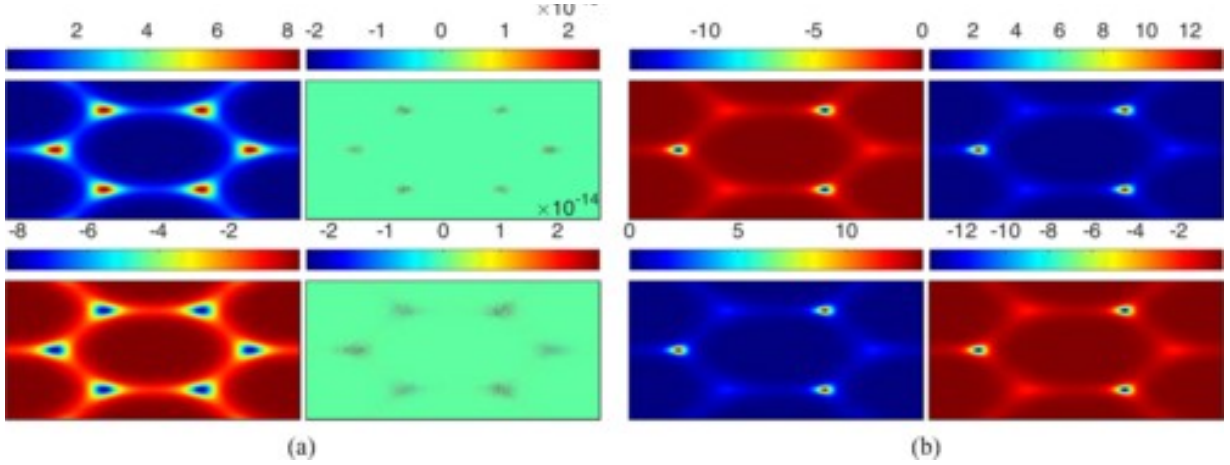
(a) (b) (c)

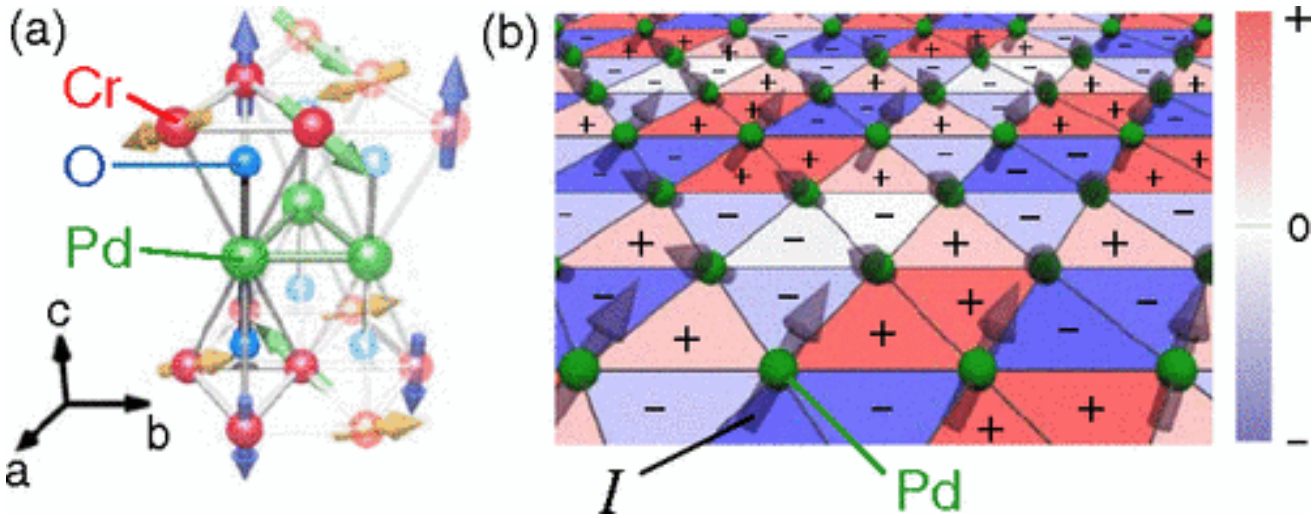

Fe
C
N
PDOS (a.u.)

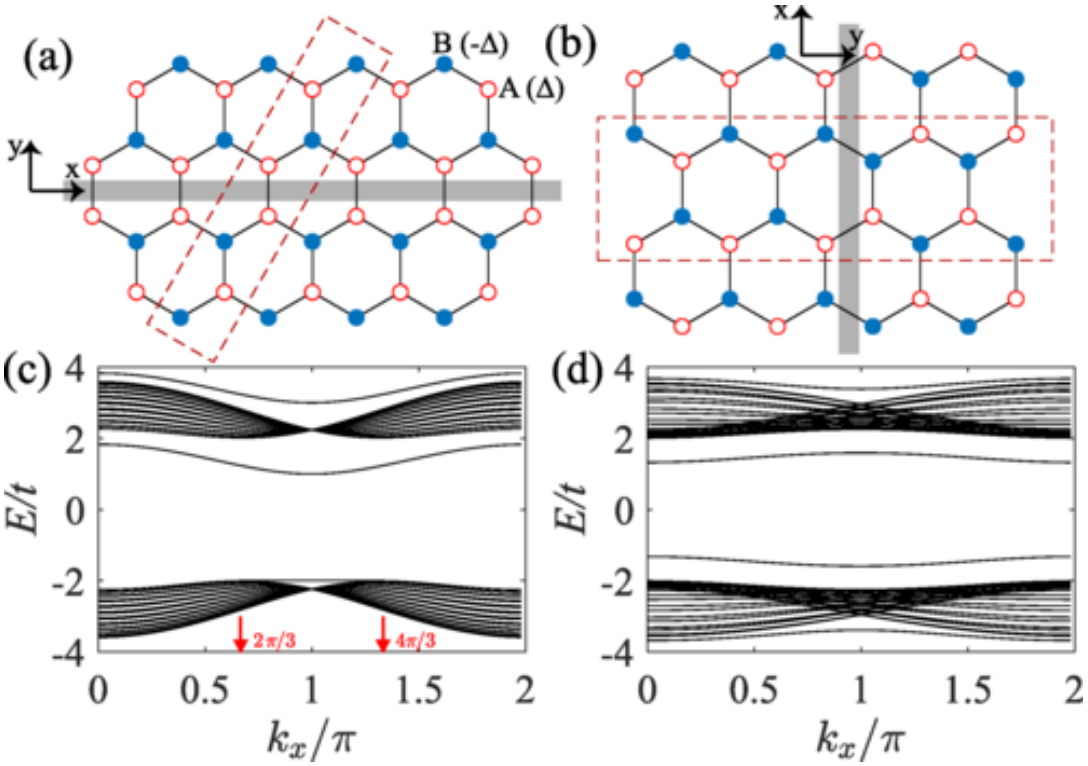
(a) (b) (c) (d)

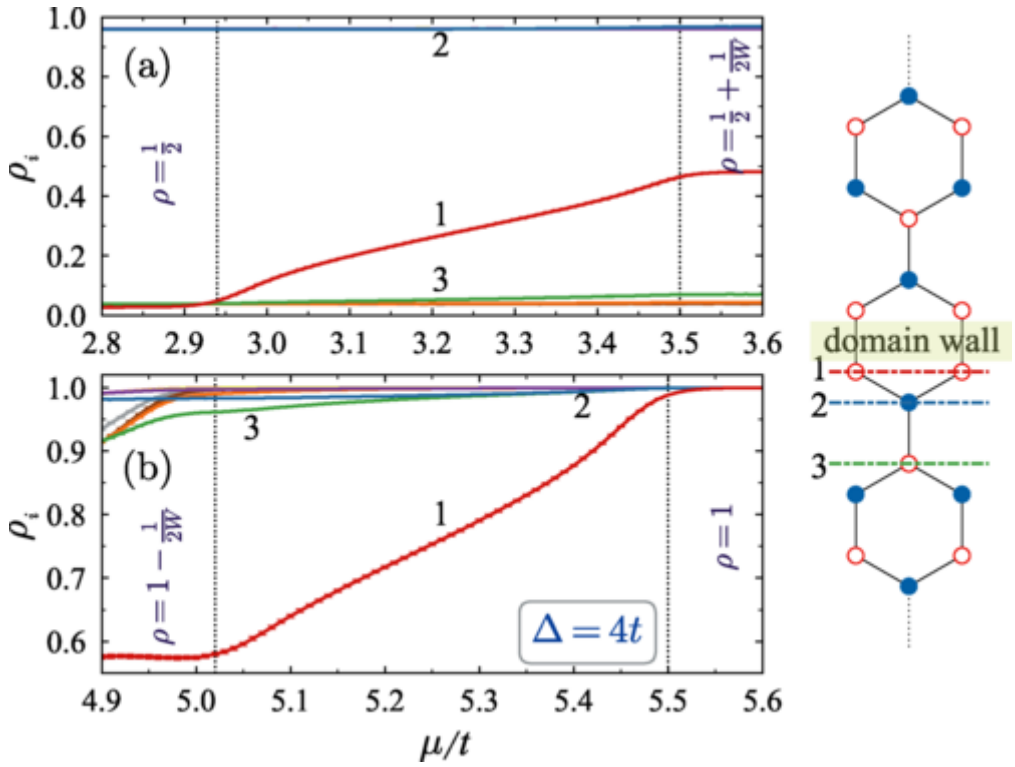

(a) Δ<0
(b) Δ=0
(c) Δ>0
μ3
μ1
μ2
ρ1
ρ3
ρ2
a
y
x

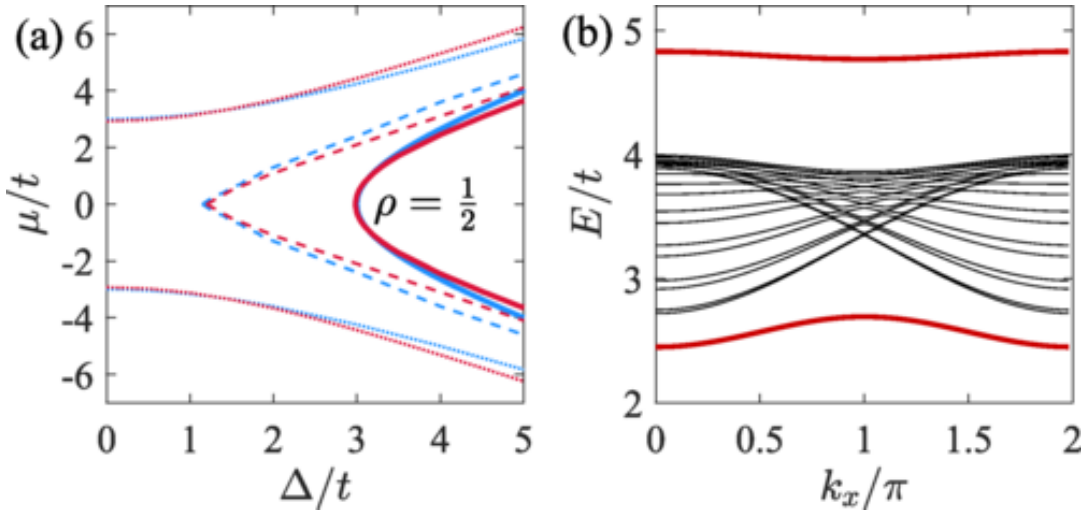


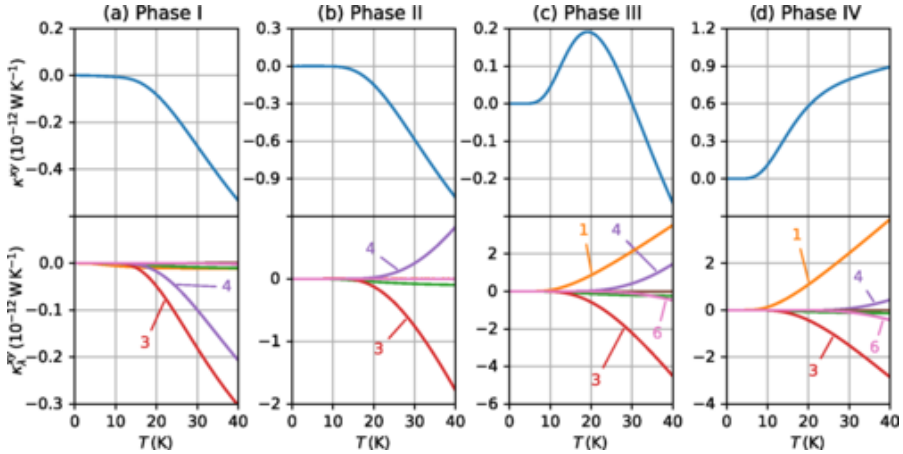

2 4 6 8
-2 -1 0 1 2
-10 -5 0 2 4 6 8 10 12
×10-14
-8 -6 -4 -2
-2 -1 0 1 2
0 5 10
-12 -10 -8 -6 -4 -2
(a)
(b)

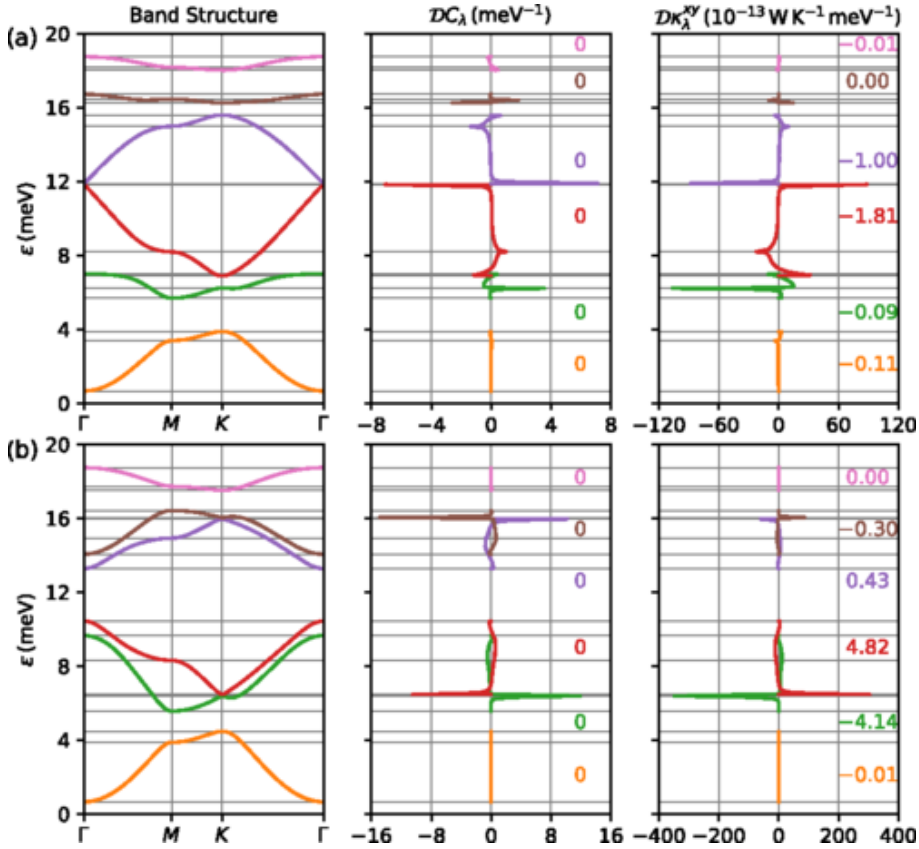

(a)
Cr
O
Pd
c
b
a
(b)
+
0
–
I
Pd

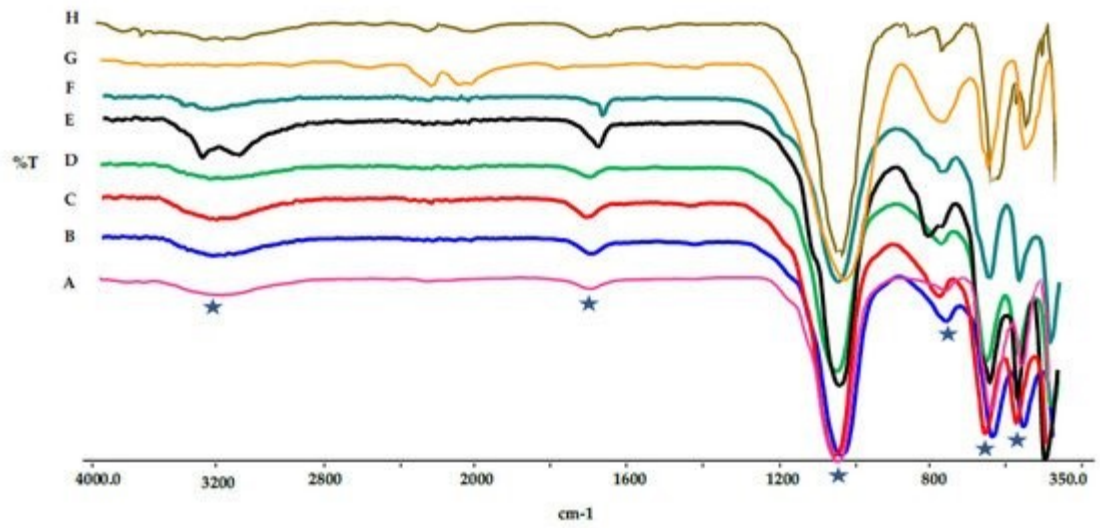

(a)
B (-Δ)
A (Δ)
y
x
(b)
x
y
(c)
E/t
2π/3
4π/3
k_x/π
(d)
E/t
k_x/π

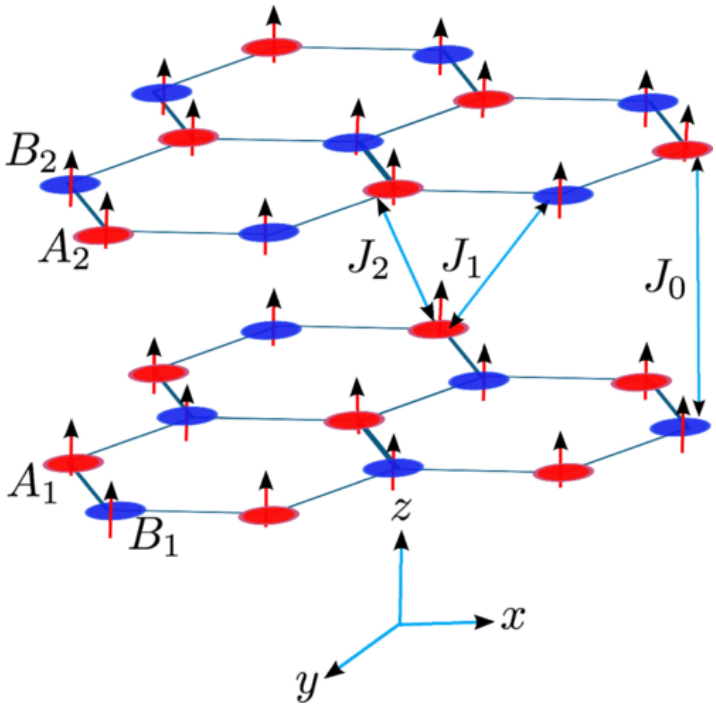

(a)
ρ_i
$\rho=\frac{1}{2}$
$\rho=\frac{1}{2}+\frac{1}{2W}$
1
2
3
(b)
ρ_i
$\rho=1-\frac{1}{2W}$
$\rho=1$
$\Delta=4t$
μ/t
domain wall
1
2
3

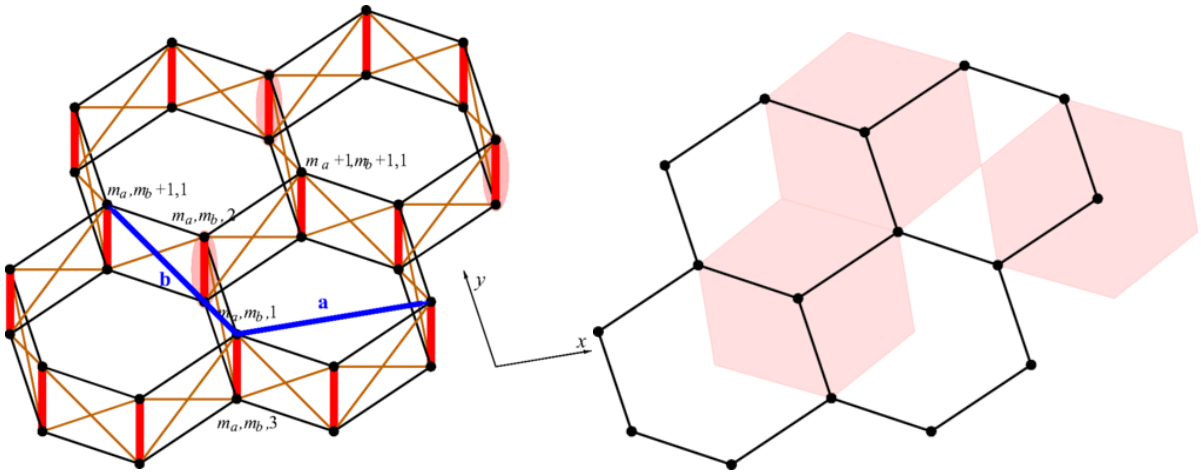

(a)
μ/t
$\rho=\frac{1}{2}$
Δ/t
(b)
E/t
k_x/π

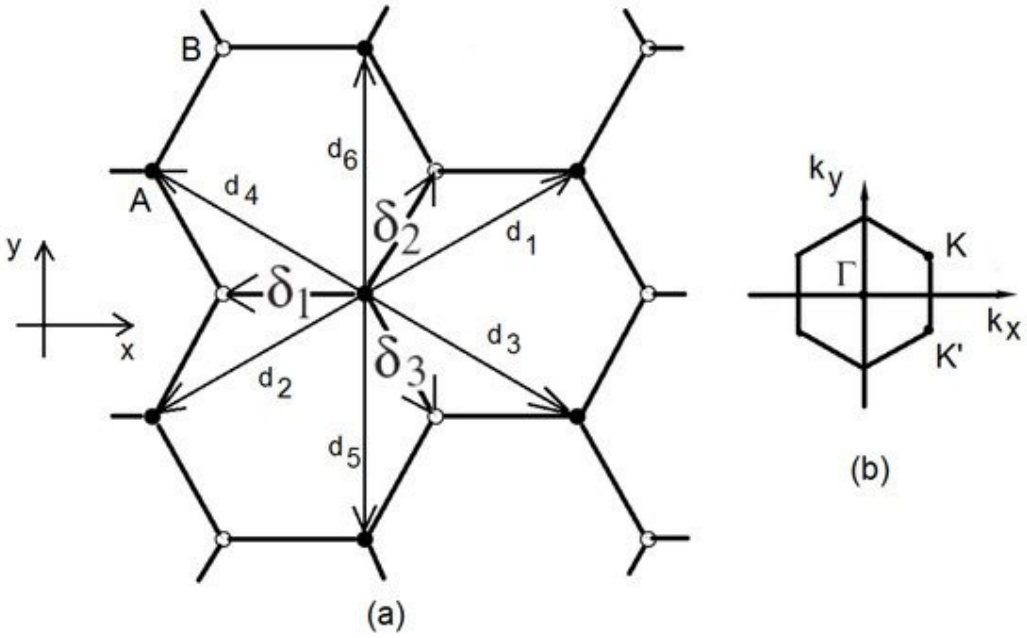

(a) Phase I
(b) Phase II
(c) Phase III
(d) Phase IV
κ^{xy} (10^{-12} W K^{-1})
κ_λ^{xy} (10^{-12} W K^{-1})
T (K)

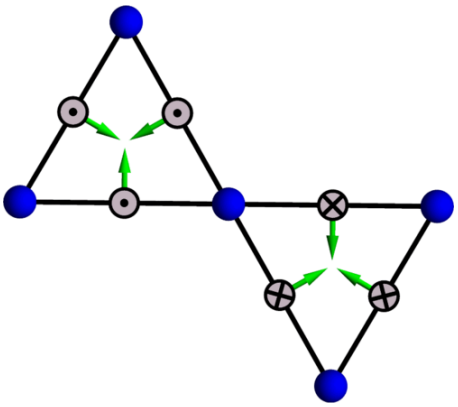

Band Structure
$\mathcal{D}C_\lambda$ (meV^{-1})
$\mathcal{D}\kappa_\lambda^{xy}$ (10^{-13} W K^{-1} meV^{-1})
(a)
(b)
ε (meV)
Γ M K Γ
0 0 0 0 0
−0.01 0.00 −1.00 −1.81 −0.09 −0.11
0.00 −0.30 0.43 4.82 −4.14 −0.01

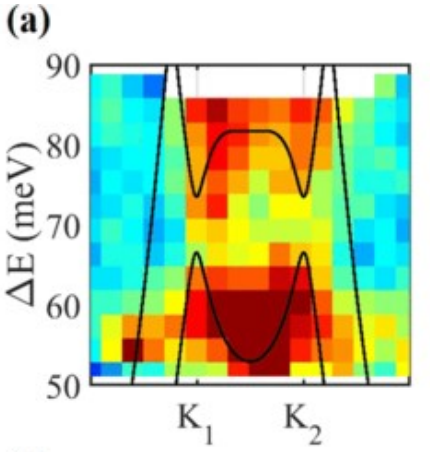

H
G
F
E
D
C
B
A
%T
4000.0 3200 2800 2000 1600 1200 800 350.0
cm-1

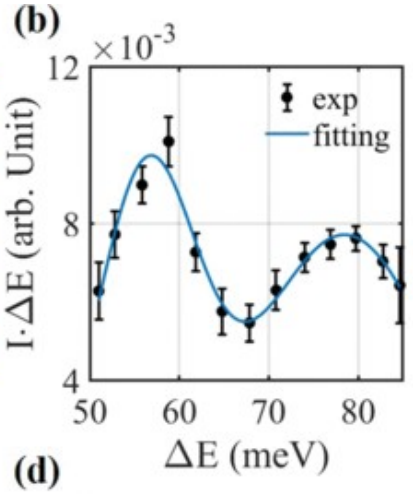

B_2
A_2
J_2
J_1
J_0
A_1
B_1
z
x
y

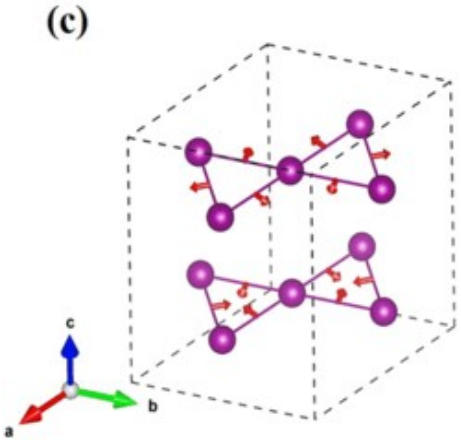

$m_a, m_b+1, 1$
$m_a+1, m_b+1, 1$
$m_a, m_b, 2$
b
a
$m_a, m_b, 1$
$m_a, m_b, 3$
y
x

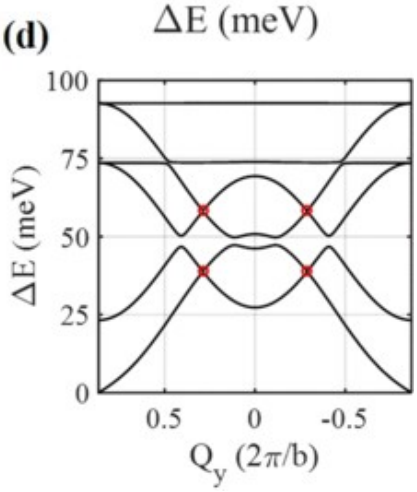

B
A
d_6
d_4
δ_2
d_1
δ_1
d_3
d_2
δ_3
d_5
y
x
(a)
k_y
K
Γ
k_x
K'
(b)

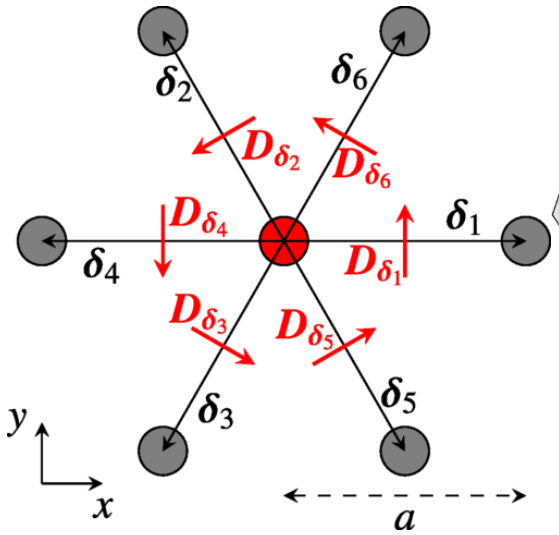


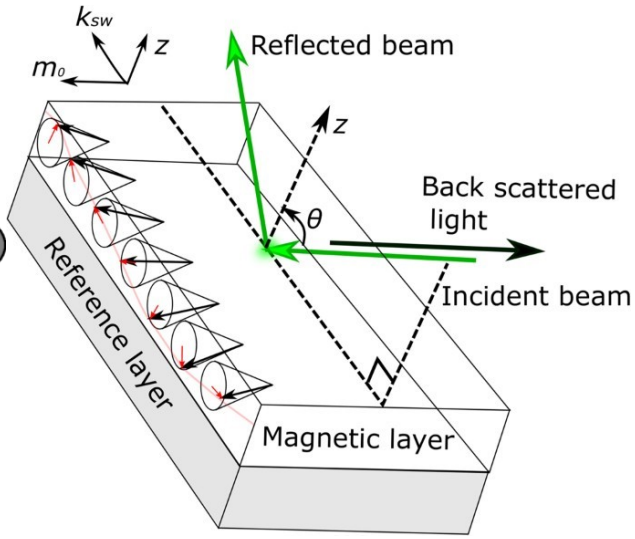

(a)
90
80
70
60
50
ΔE (meV)
K1
K2

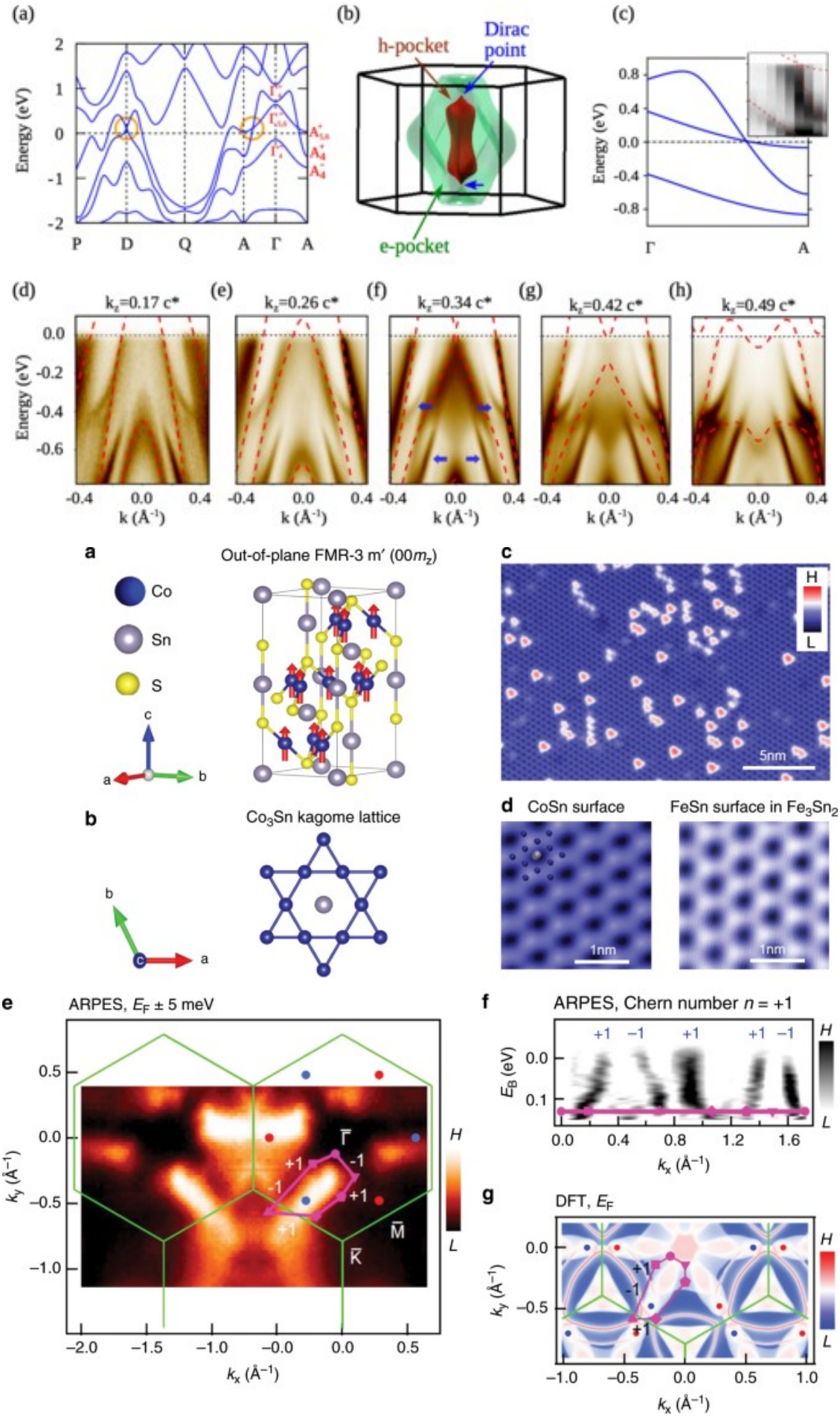

(b)
×10-3
12
8
4
I·ΔE (arb. Unit)
exp
fitting
50
60
70
80
ΔE (meV)

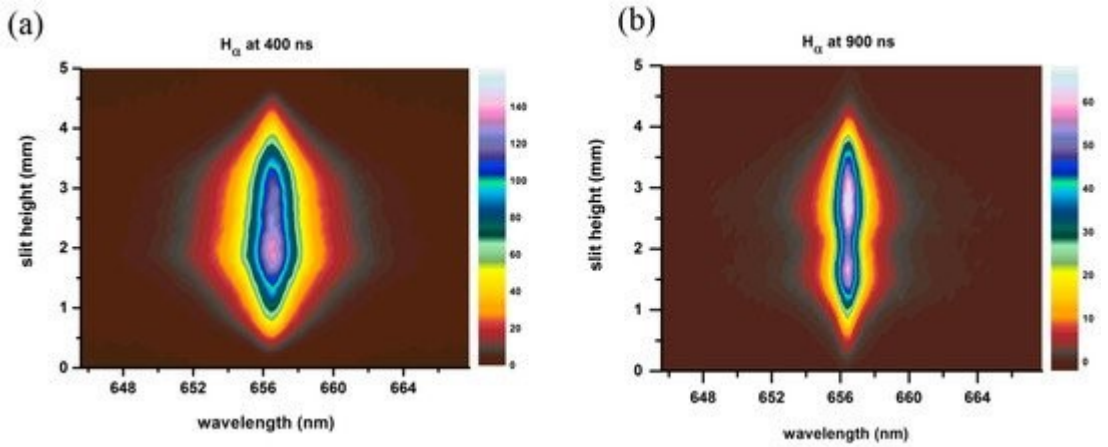

(c)
c
b
a

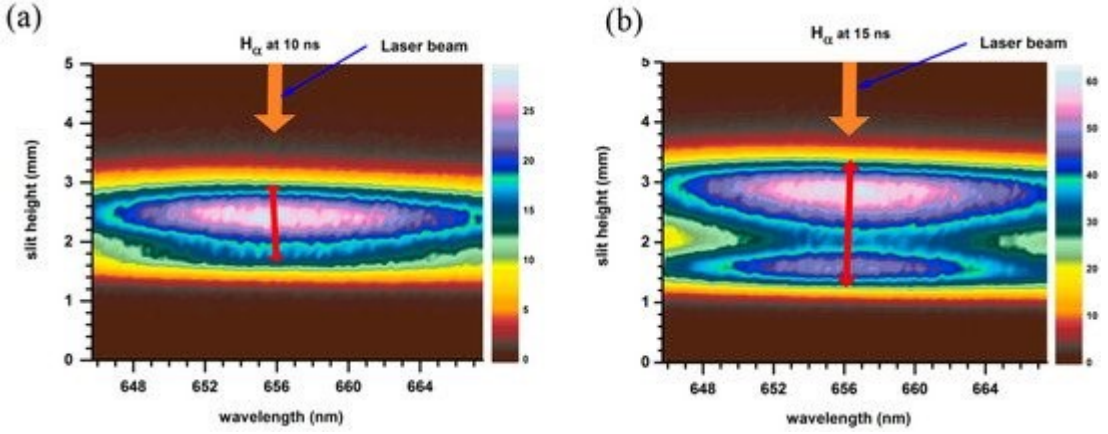

(d)
100
75
50
25
0
ΔE (meV)
0.5
0
-0.5
Qy (2π/b)

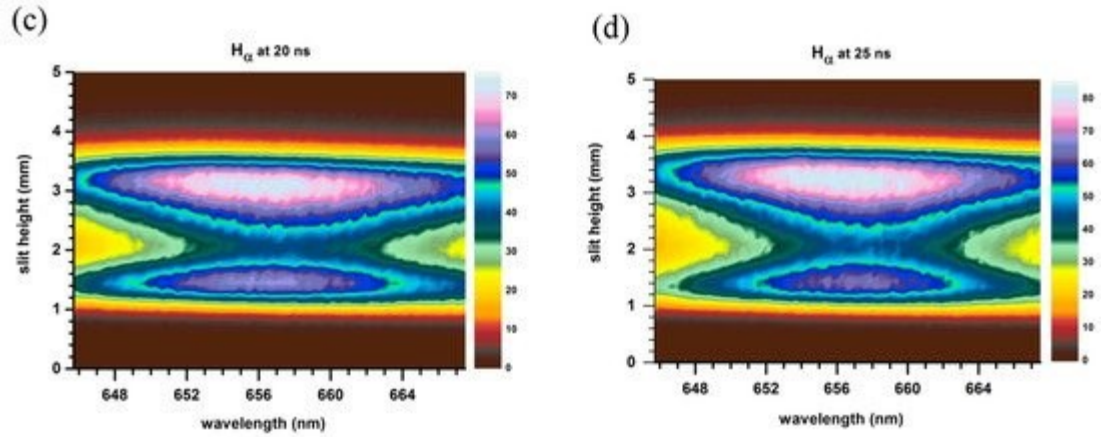

δ2
δ6
Dδ2
Dδ6
Dδ4
δ1
δ4
Dδ1
Dδ3
Dδ5
δ3
δ5
y
x
a

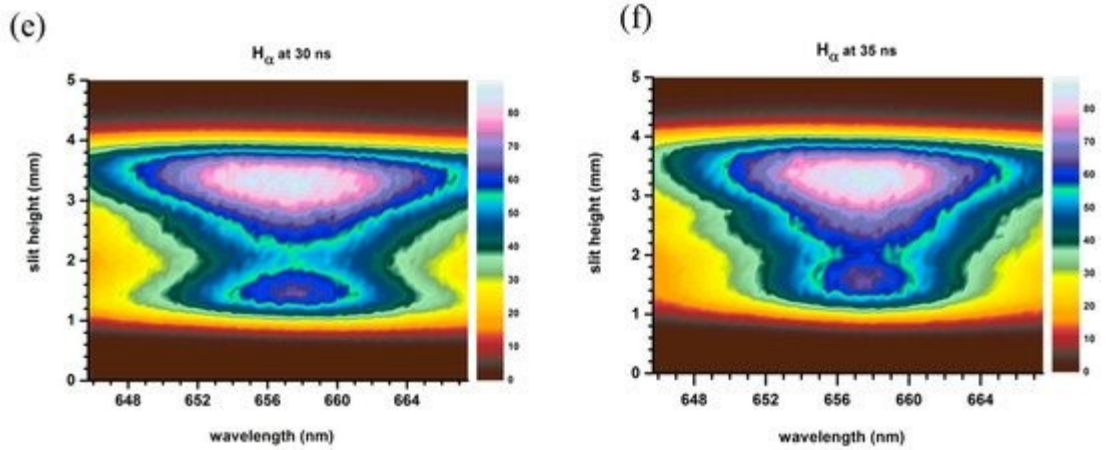

ksw
z
m0
Reflected beam
z
Back scattered
light
θ
Incident beam
Reference layer
Magnetic layer

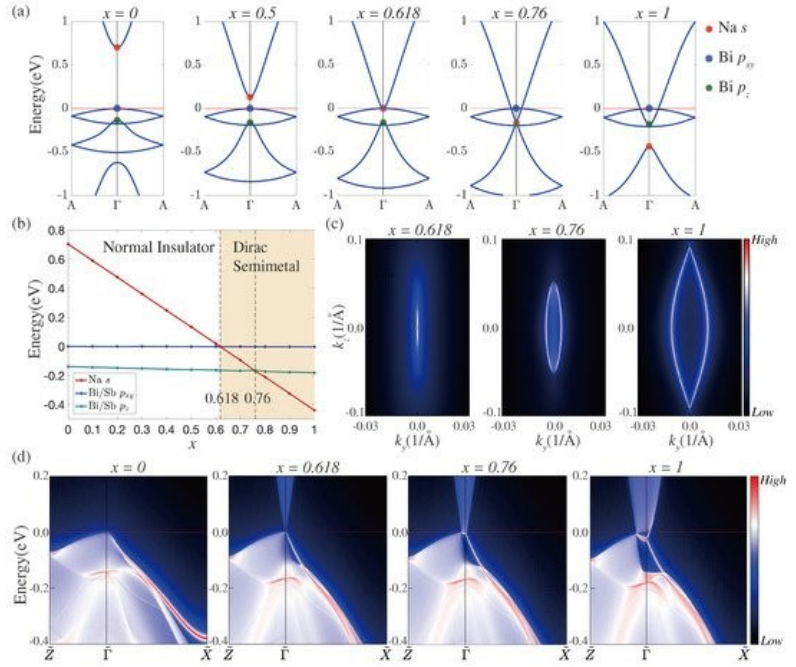

(a)
(b)
(c)
Energy (eV)
P
D
Q
A
Γ
A
h-pocket
Dirac point
e-pocket
(d)
(e)
(f)
(g)
(h)
k_z=0.17 c*
k_z=0.26 c*
k_z=0.34 c*
k_z=0.42 c*
k_z=0.49 c*
k (Å^-1)
a
Out-of-plane FMR-3 m′ (00m_z)
Co
Sn
S
b
Co3Sn kagome lattice
c
H
L
5nm
d
CoSn surface
FeSn surface in Fe3Sn2
1nm
e
ARPES, E_F ± 5 meV
k_y (Å^-1)
k_x (Å^-1)
Γ̄
M̄
K̄
f
ARPES, Chern number n = +1
E_B (eV)
g
DFT, E_F

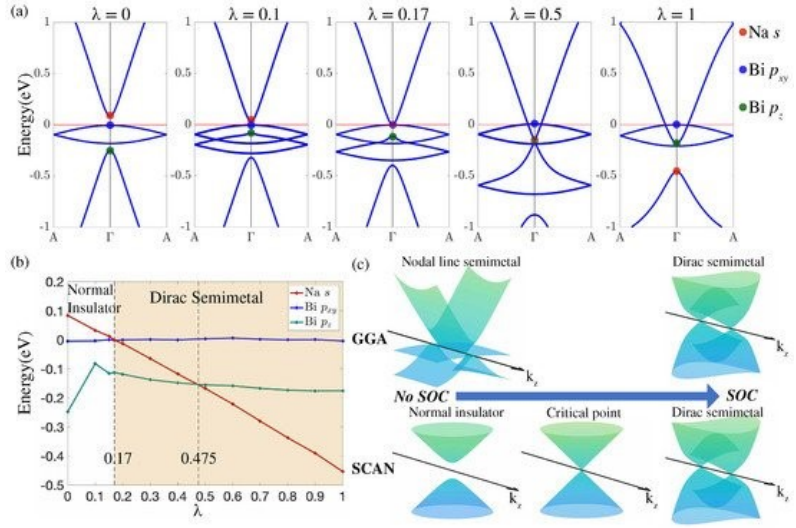

(a)
H_α at 400 ns
slit height (mm)
wavelength (nm)
(b)
H_α at 900 ns
slit height (mm)
wavelength (nm)

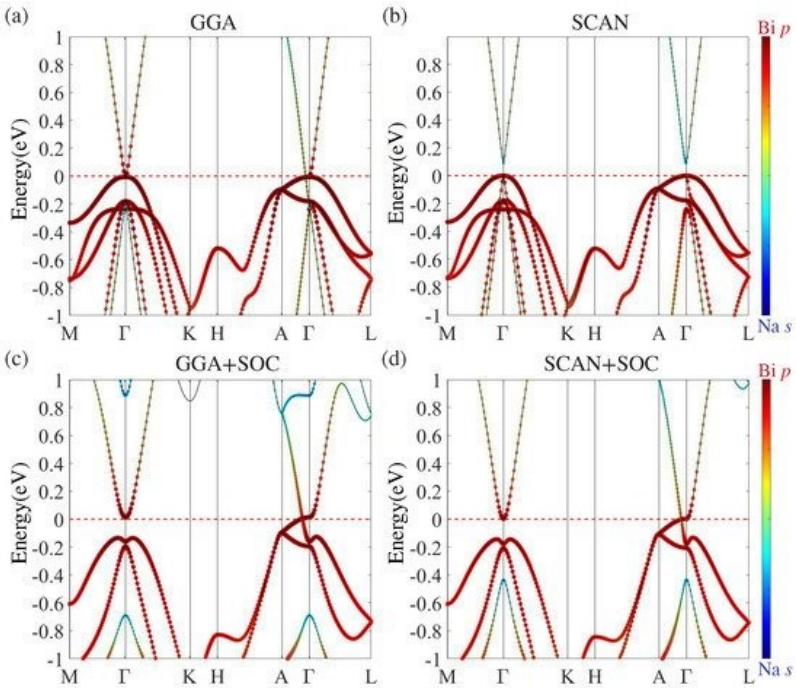

(a)
H_α at 10 ns
Laser beam
slit height (mm)
wavelength (nm)
(b)
H_α at 15 ns
Laser beam
slit height (mm)
wavelength (nm)

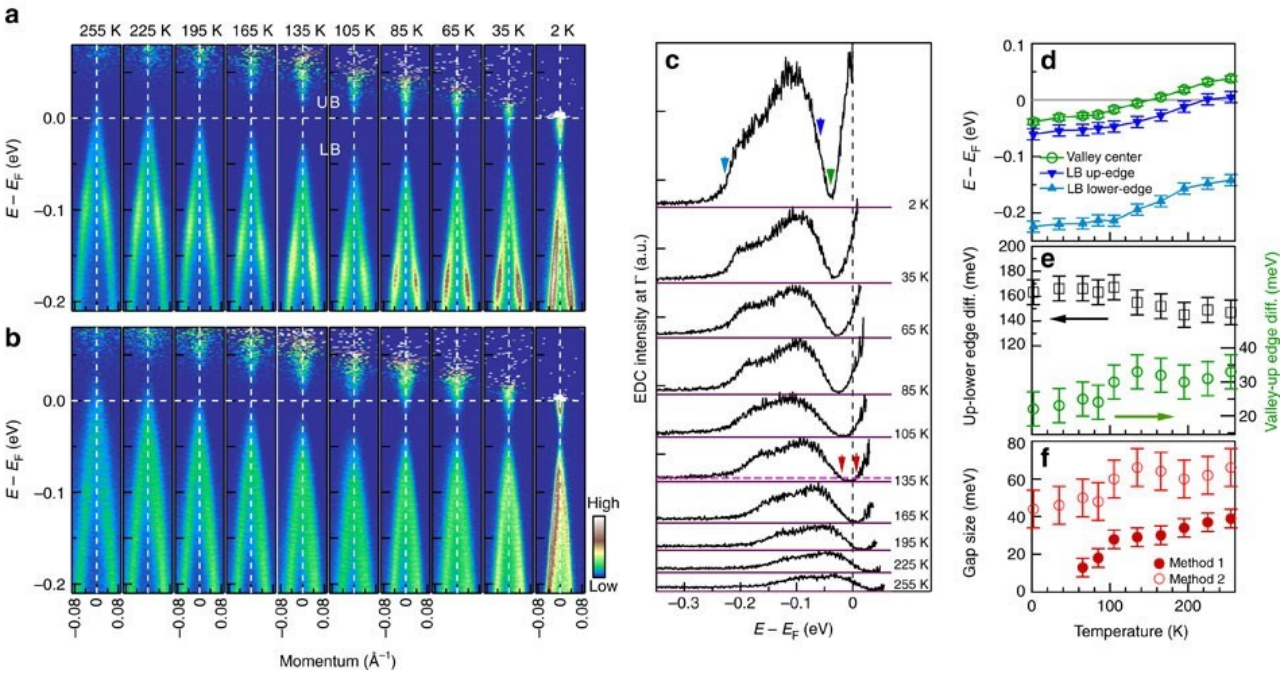

(c)
H_α at 20 ns
slit height (mm)
wavelength (nm)
(d)
H_α at 25 ns
slit height (mm)
wavelength (nm)

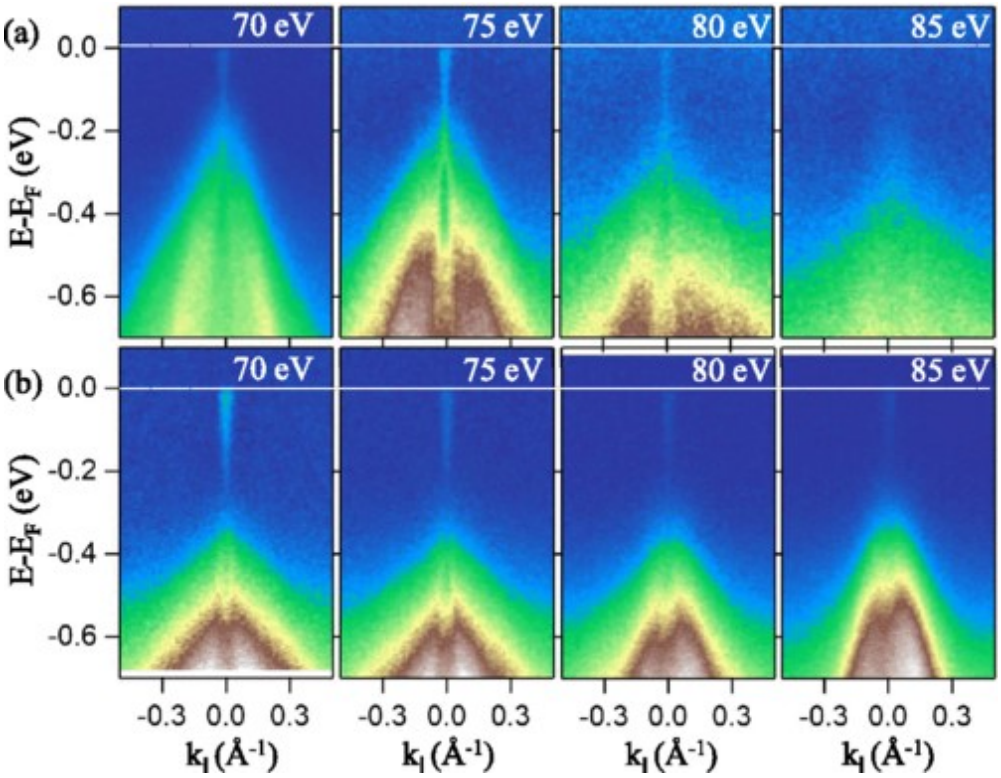

(e)
H_α at 30 ns
slit height (mm)
wavelength (nm)
(f)
H_α at 35 ns
slit height (mm)
wavelength (nm)

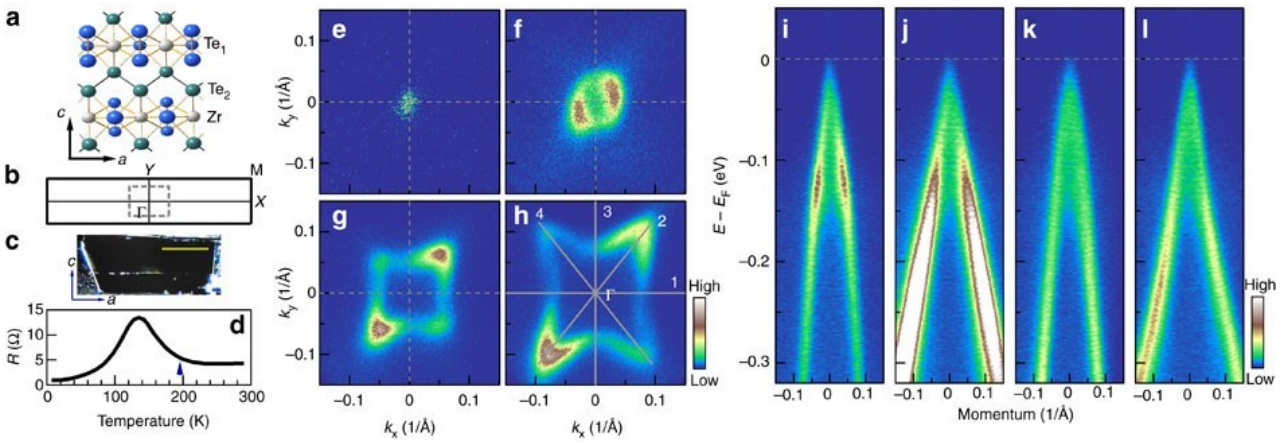

(a)
x = 0
x = 0.5
x = 0.618
x = 0.76
x = 1
Energy(eV)
Na s
Bi p_{xy}
Bi p_z
A Γ A
(b)
Normal Insulator
Dirac Semimetal
Energy(eV)
Na s
Bi/Sb p_{xy}
Bi/Sb p_z
0.618 0.76
x
(c)
x = 0.618
x = 0.76
x = 1
High
Low
k_y(1/Å)
k_x(1/Å)
(d)
x = 0
x = 0.618
x = 0.76
x = 1
High
Low
Energy(eV)
$\bar{Z}$ $\bar{\Gamma}$ $\bar{X}$

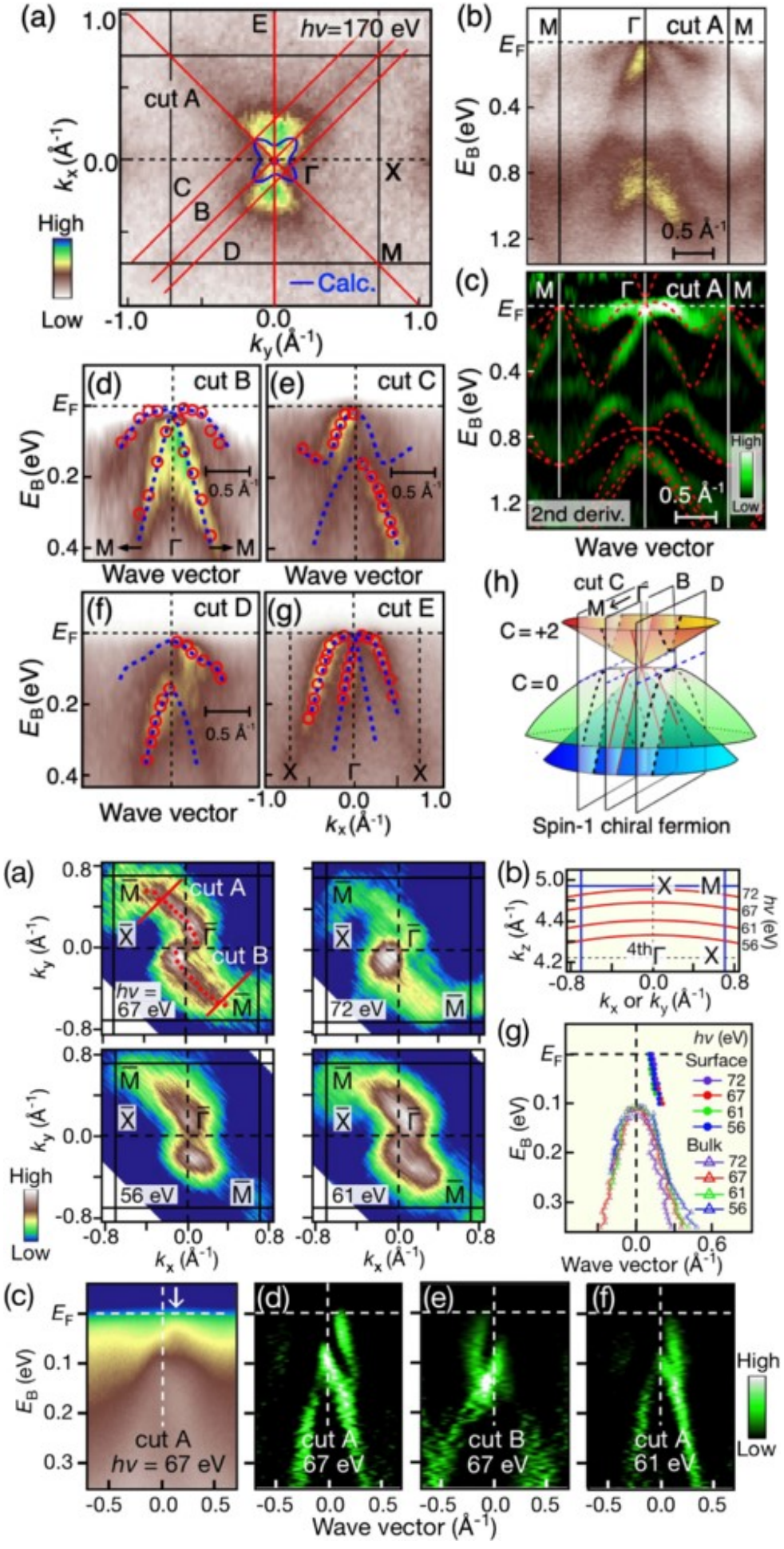

(a)
λ = 0
λ = 0.1
λ = 0.17
λ = 0.5
λ = 1
Energy(eV)
Na s
Bi p_{xy}
Bi p_z
A Γ A
(b)
Normal Insulator
Dirac Semimetal
Na s
Bi p_{xy}
Bi p_z
Energy(eV)
0.17
0.475
λ
(c)
Nodal line semimetal
Dirac semimetal
GGA
k_z
No SOC
SOC
Normal insulator
Critical point
Dirac semimetal
SCAN

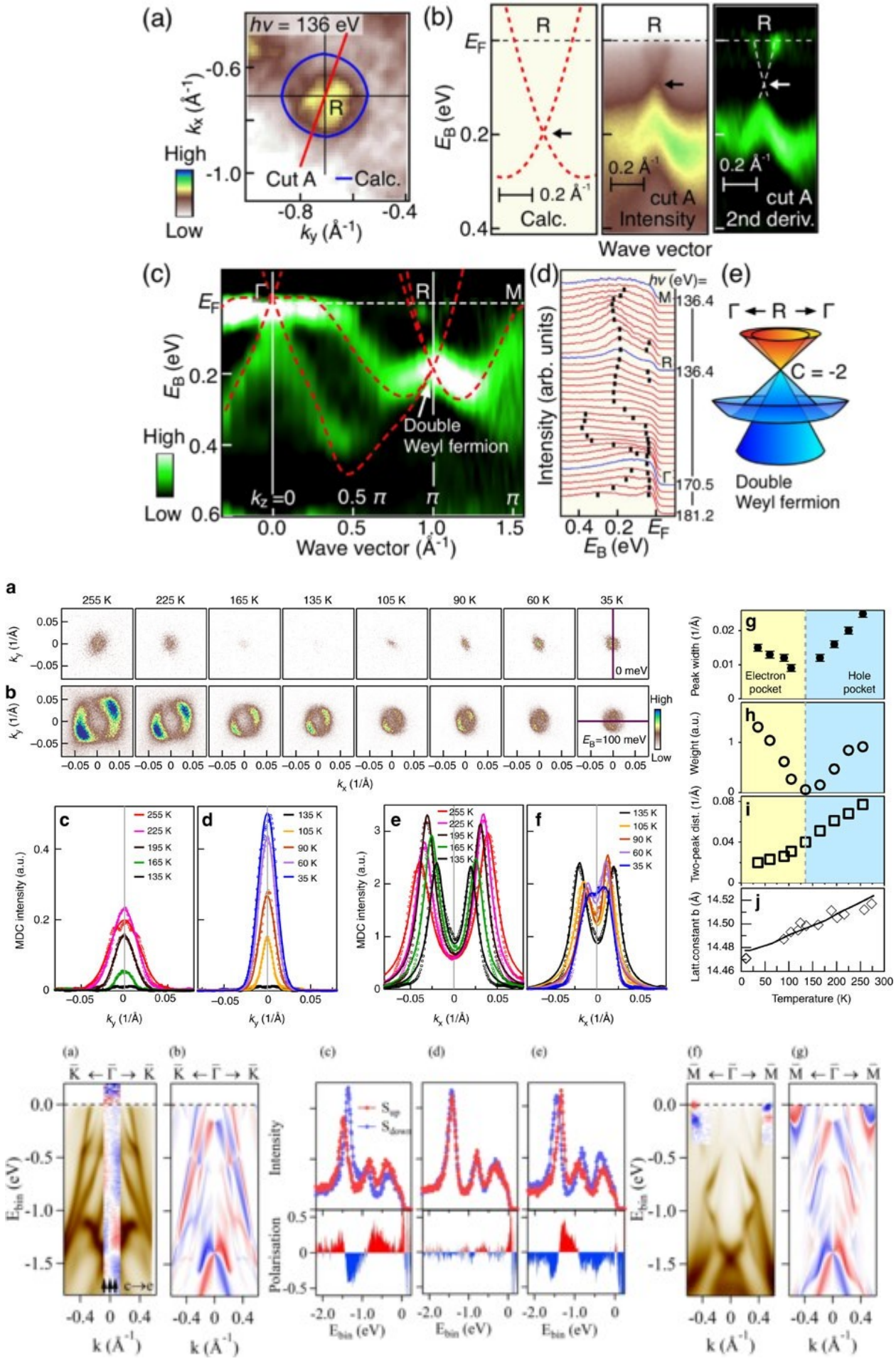

(a)
GGA
(b)
SCAN
Bi p
Na s
Energy(eV)
M Γ K H A Γ L
(c)
GGA+SOC
(d)
SCAN+SOC

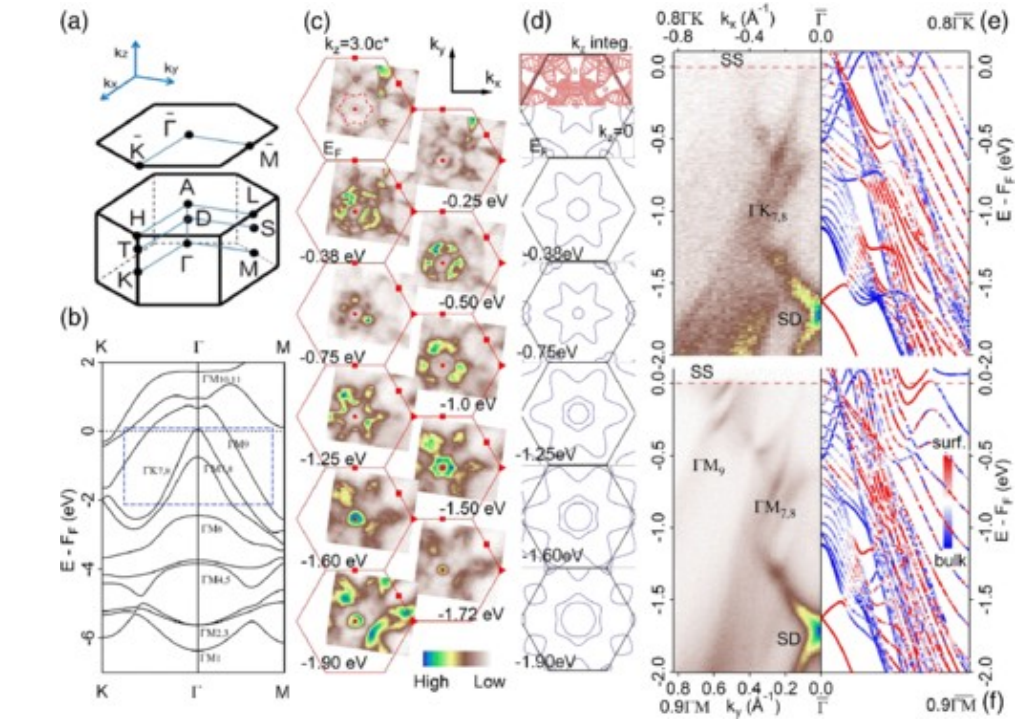

a
255 K 225 K 195 K 165 K 135 K 105 K 85 K 65 K 35 K 2 K
UB
LB
E − E_F (eV)
b
High
Low
−0.08 0 0.08
Momentum (Å^−1)
c
EDC intensity at Γ (a.u.)
2 K
35 K
65 K
85 K
105 K
135 K
165 K
195 K
225 K
255 K
−0.3 −0.2 −0.1 0
E − E_F (eV)
d
E − E_F (eV)
Valley center
LB up-edge
LB lower-edge
e
Up-lower edge diff. (meV)
Valley-up edge diff. (meV)
f
Gap size (meV)
Method 1
Method 2
0 100 200
Temperature (K)

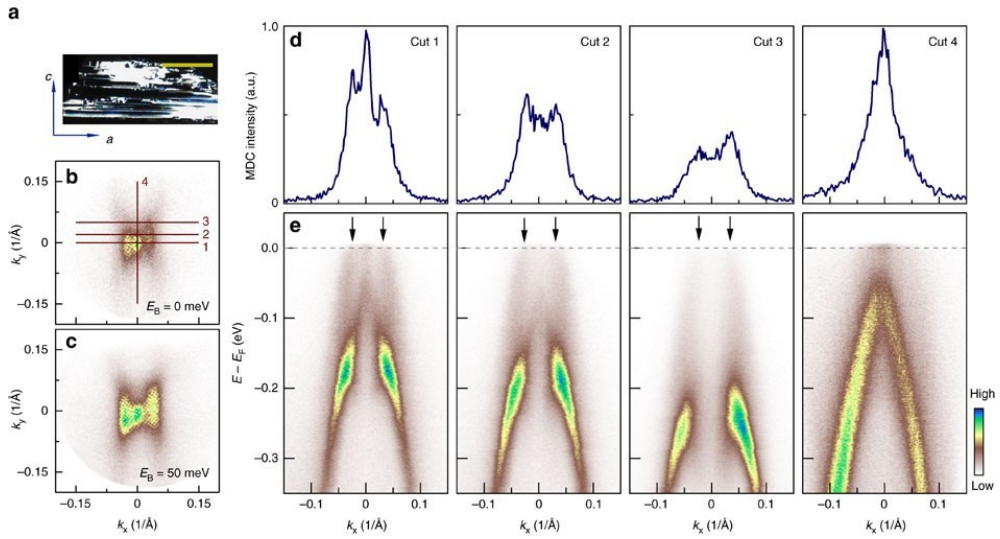

(a)
70 eV
75 eV
80 eV
85 eV
E-E_F (eV)
0.0
-0.2
-0.4
-0.6
(b)
-0.3 0.0 0.3
k_∥ (Å^-1)

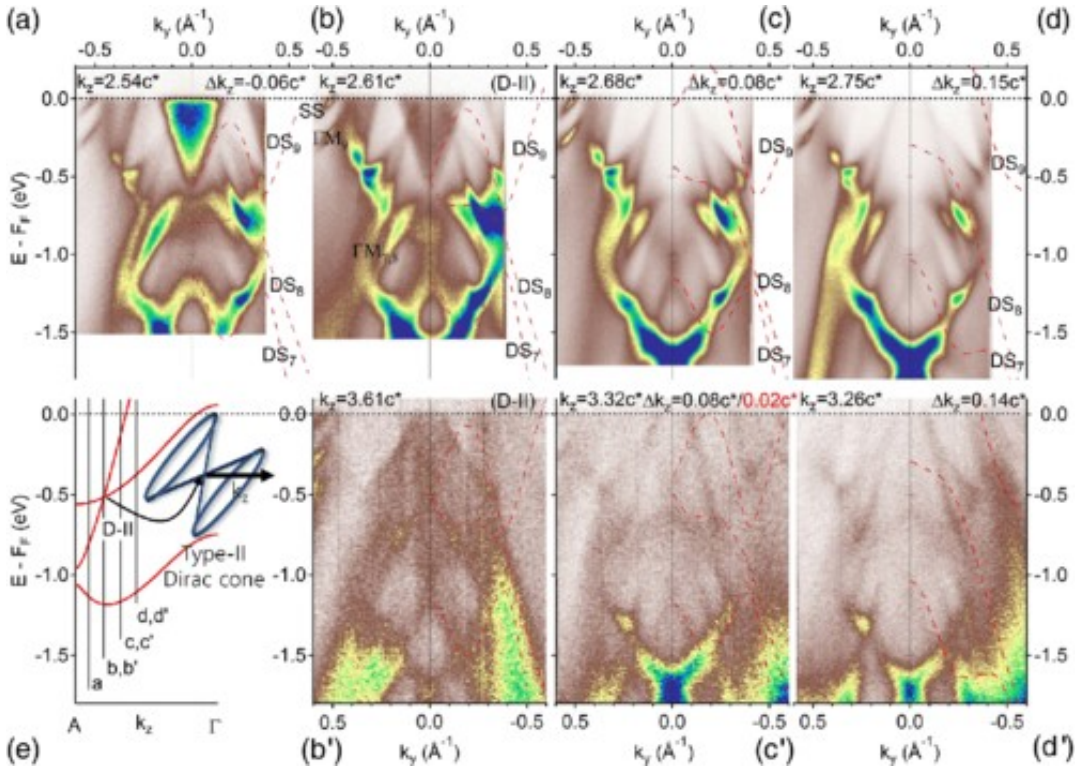

a
Te_1
Te_2
Zr
c
a
b
Y
M
X
Γ
c
d
R (Ω)
Temperature (K)
e
f
g
h
k_y (1/Å)
k_x (1/Å)
4
3
2
1
Γ
High
Low
i
j
k
l
E − E_F (eV)
Momentum (1/Å)

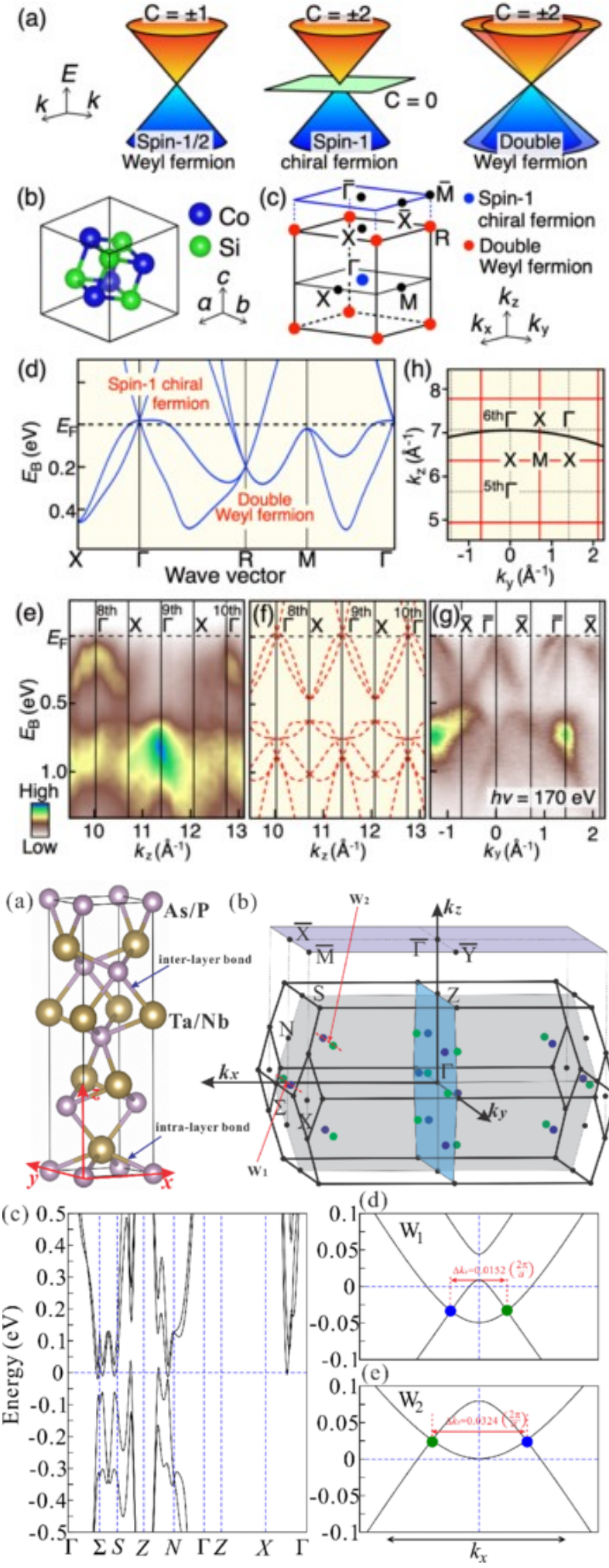

(a)
E
hν=170 eV
cut A
C
B
D
Γ
X
M
Calc.
High
Low
k_x (Å^-1)
k_y (Å^-1)
(b)
M
Γ
cut A
M
E_F
E_B (eV)
0.5 Å^-1
(c)
2nd deriv.
Wave vector
(d)
cut B
(e)
cut C
(f)
cut D
(g)
cut E
(h)
C = +2
C = 0
Spin-1 chiral fermion
(a)
hν = 67 eV
72 eV
56 eV
61 eV
(b)
4th
hν (eV)
k_x or k_y (Å^-1)
(g)
Surface
Bulk
Wave vector (Å^-1)
(c)
cut A
hν = 67 eV
(d)
cut A
67 eV
(e)
cut B
67 eV
(f)
cut A
61 eV

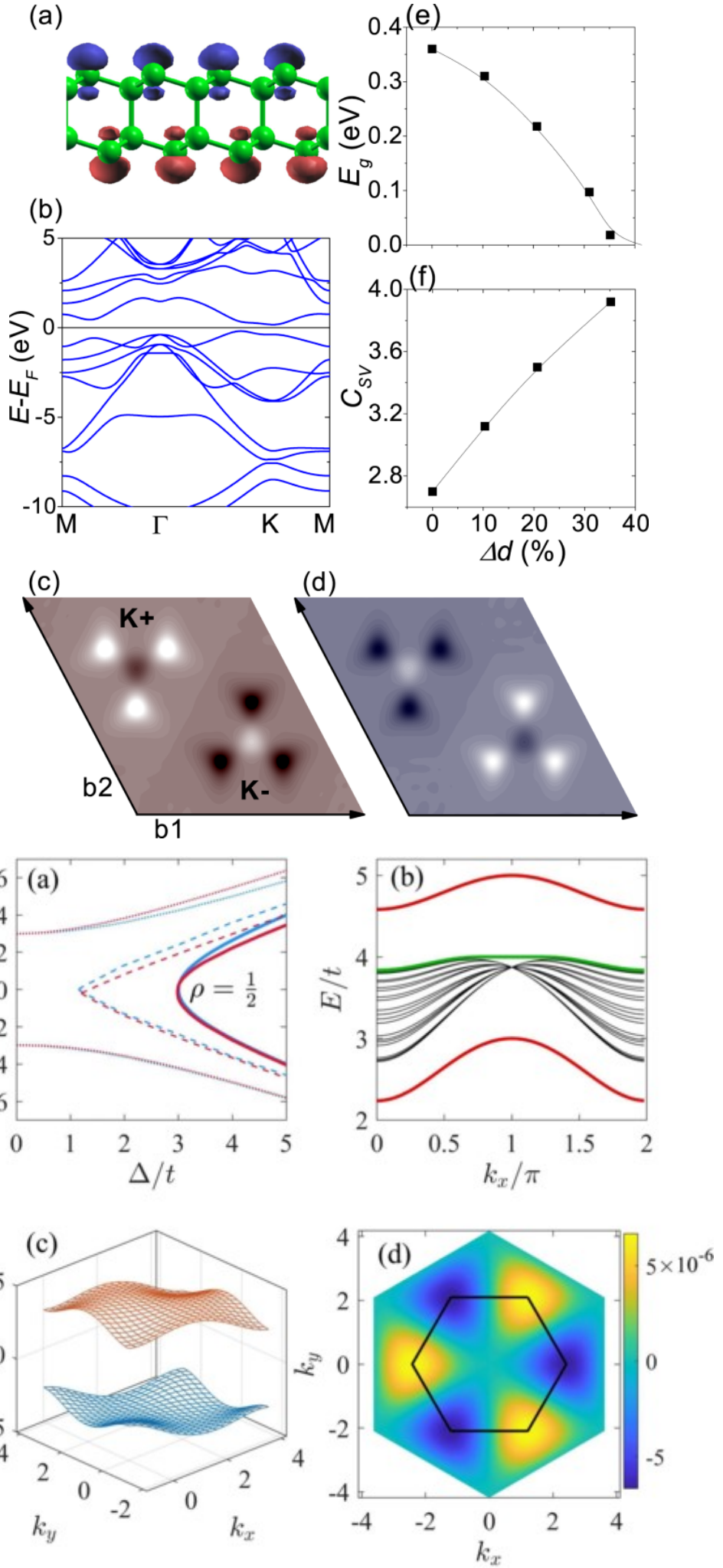

(a)
hv = 136 eV
R
Cut A
Calc.
High
Low
k_x (Å^{-1})
k_y (Å^{-1})
(b)
R
E_F
E_B (eV)
0.2 Å^{-1}
Calc.
cut A
Intensity
cut A
2nd deriv.
Wave vector
(c)
Γ
R
M
E_F
E_B (eV)
Double
Weyl fermion
k_z=0
0.5 π
π
Wave vector (Å^{-1})
(d)
hv (eV)=
136.4
136.4
170.5
181.2
Intensity (arb. units)
E_B (eV)
(e)
Γ ← R → Γ
C = -2
Double
Weyl fermion
a
255 K
225 K
165 K
135 K
105 K
90 K
60 K
35 K
0 meV
E_B=100 meV
High
Low
k_y (1/Å)
k_x (1/Å)
b
c
d
e
f
MDC intensity (a.u.)
g
Peak width (1/Å)
Electron pocket
Hole pocket
h
Weight (a.u.)
i
Two-peak dist. (1/Å)
j
Latt.constant b (Å)
Temperature (K)
(a)
(b)
(c)
(d)
(e)
(f)
(g)
$\bar{K} \leftarrow \bar{\Gamma} \rightarrow \bar{K}$
$\bar{M} \leftarrow \bar{\Gamma} \rightarrow \bar{M}$
E_{bin} (eV)
k (Å^{-1})
c→e
Intensity
Polarisation
S_{up}
S_{down}

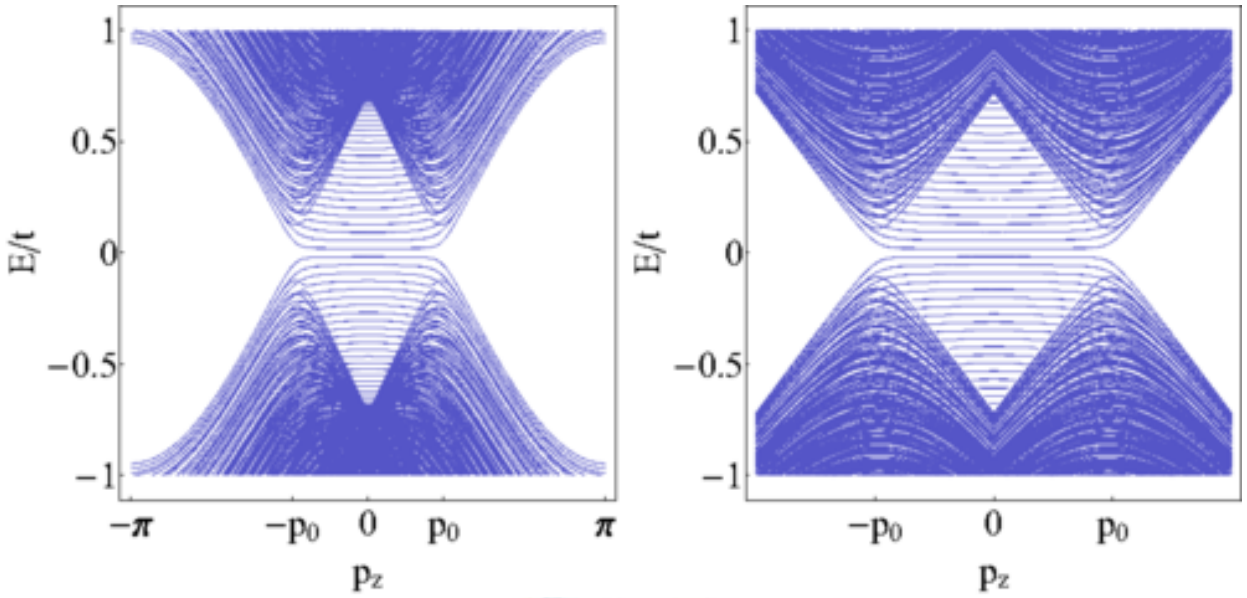

(a)
(b)
(c)
(d)
(e)
(f)
SS
SD
surf.
bulk
High
Low

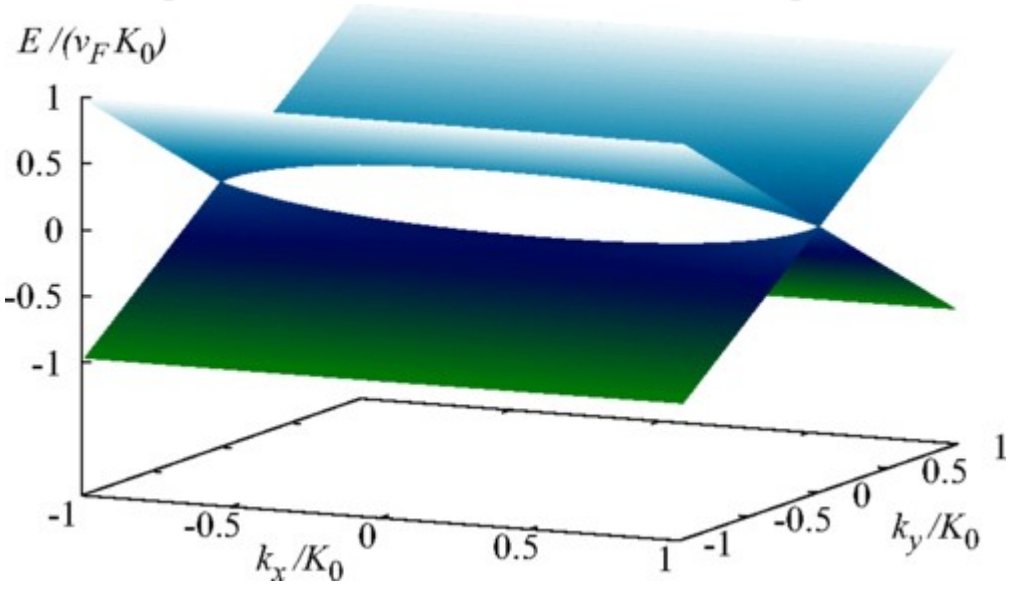

a
b
c
d
e
Cut 1
Cut 2
Cut 3
Cut 4
MDC intensity (a.u.)
High
Low

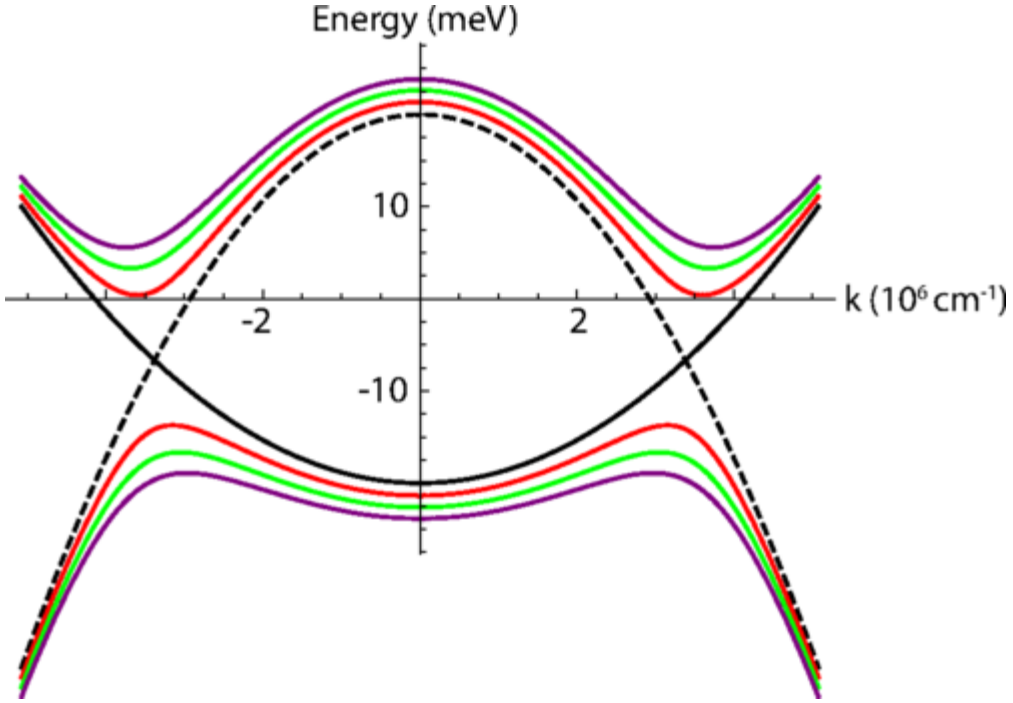

(a)
(b)
(c)
(d)
SS
D-II
Type-II
Dirac cone
(e)
(b')
(c')
(d')

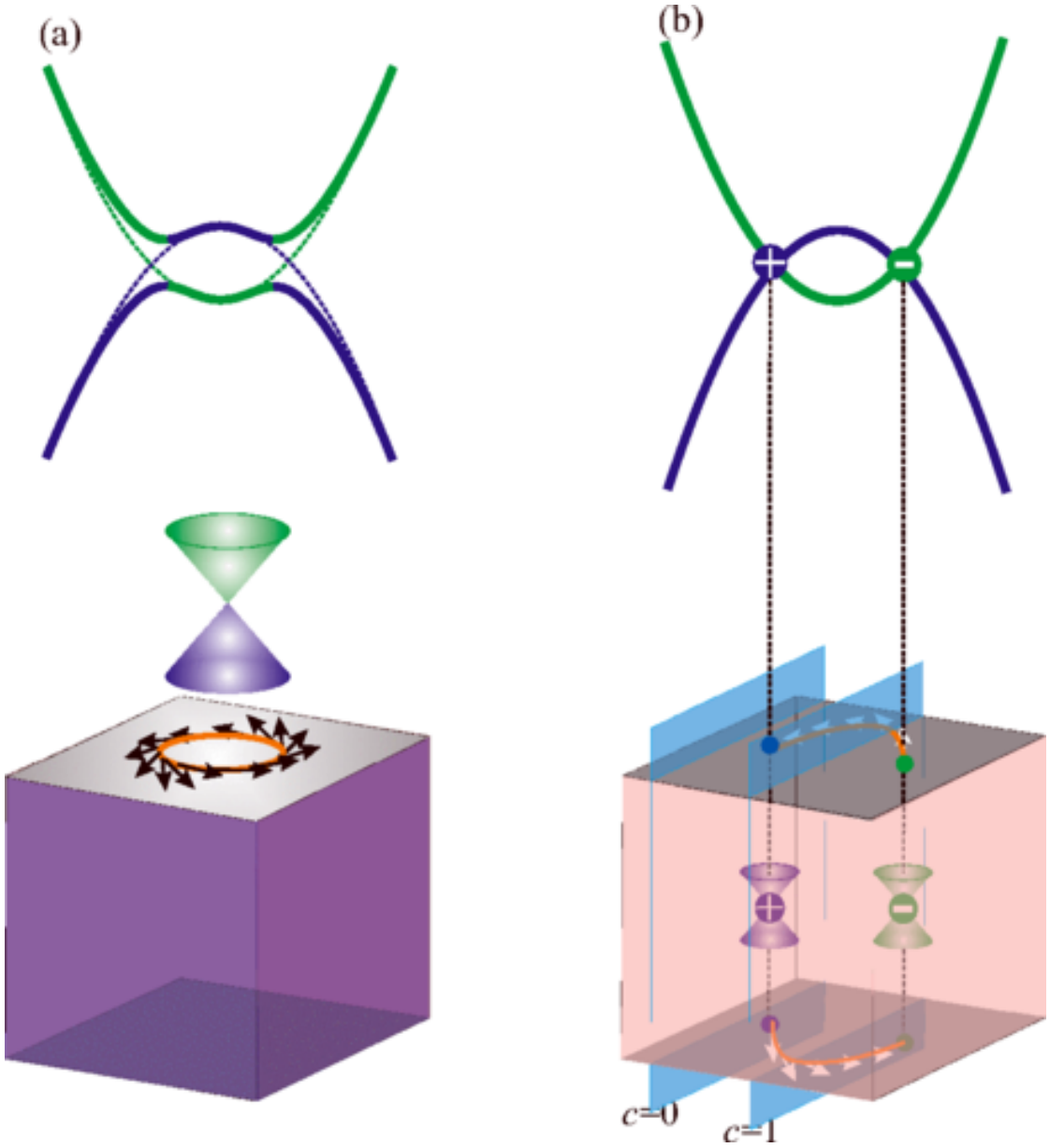

(a)
C = ±1
C = ±2
C = ±2
C = 0
E
k
k
Spin-1/2
Weyl fermion
Spin-1
chiral fermion
Double
Weyl fermion
(b)
Co
Si
c
a
b
(c)
Γ̄
M̄
X̄
X
R
Γ
X
M
Spin-1
chiral fermion
Double
Weyl fermion
k_z
k_x
k_y
(d)
Spin-1 chiral
fermion
E_F
E_B (eV)
0.2
0.4
Double
Weyl fermion
X
Γ
R
M
Γ
Wave vector
(h)
8
7
6
5
k_z (Å^-1)
6th Γ X Γ
X–M–X
5th Γ
-1
0
1
2
k_y (Å^-1)
(e)
8th
9th
10th
Γ
X
Γ
X
Γ
E_F
E_B (eV)
0.5
1.0
High
Low
10
11
12
13
k_z (Å^-1)
(f)
8th
9th
10th
Γ
X
Γ
X
Γ
10
11
12
13
k_z (Å^-1)
(g)
X̄
Γ̄
X̄
Γ̄
X̄
hv = 170 eV
-1
0
1
2
k_y (Å^-1)
(a)
As/P
inter-layer bond
Ta/Nb
intra-layer bond
z
y
x
(b)
W2
k_z
X̄
M̄
Γ̄
Ȳ
S
Z
N
k_x
Γ
Σ
X
k_y
W1
(c)
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
Energy (eV)
Γ
Σ
S
Z
N
Γ
Z
X
Γ
(d)
W1
0.1
0.05
0
-0.05
-0.1
Δk_x=0.0152 (2π/a)
(e)
W2
0.1
0.05
0
-0.05
-0.1
Δk_x=0.0324 (2π/a)
k_x

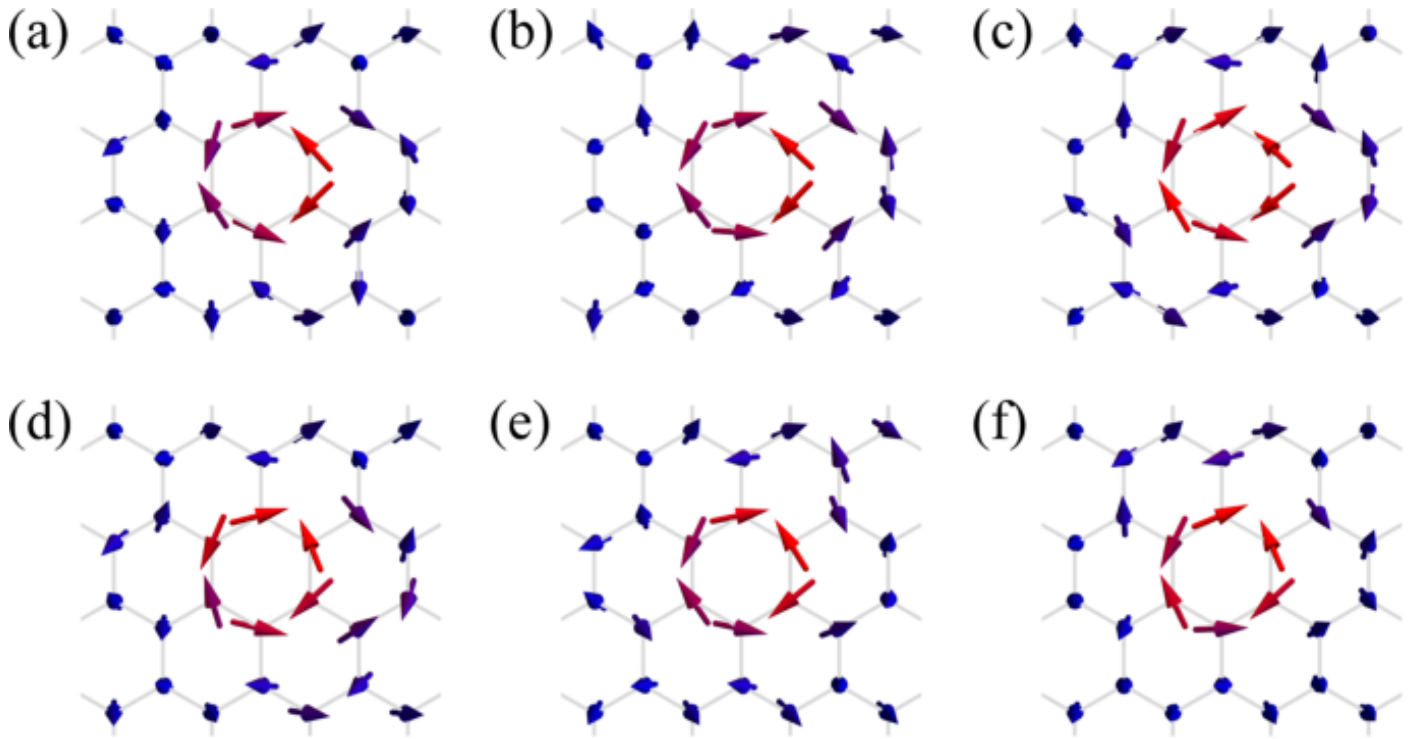

(a)
(b)
(c)
(d)
(e)
(f)
E_g (eV)
E-E_F (eV)
M
Γ
K
M
C_{SV}
Δd (%)
K+
K-
b1
b2
μ/t
$\rho = \frac{1}{2}$
Δ/t
E/t
k_x/π
k_y
k_x
5×10^{-6}

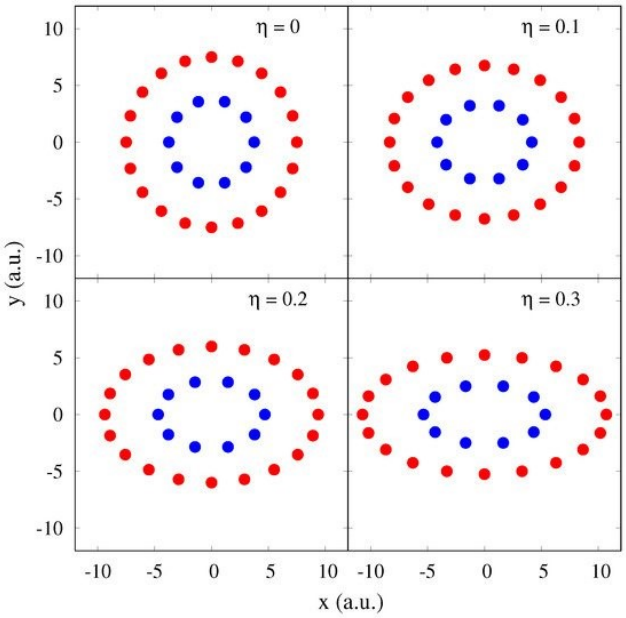

E/t
1
0.5
0
−0.5
−1
−π
−p0
0
p0
π
pz
E/t
1
0.5
0
−0.5
−1
−p0
0
p0
pz

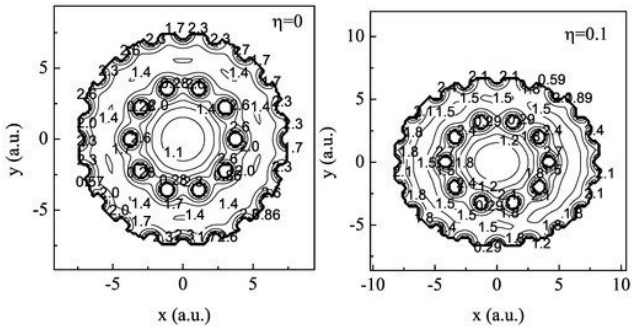

E /(vF K0)
1
0.5
0
-0.5
-1
-1
-0.5
0
0.5
1
kx /K0
-1
-0.5
0
0.5
1
ky /K0

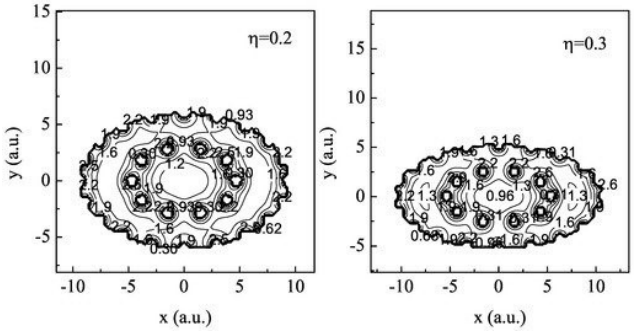

Energy (meV)
10
-10
-2
2
k (10⁶ cm⁻¹)

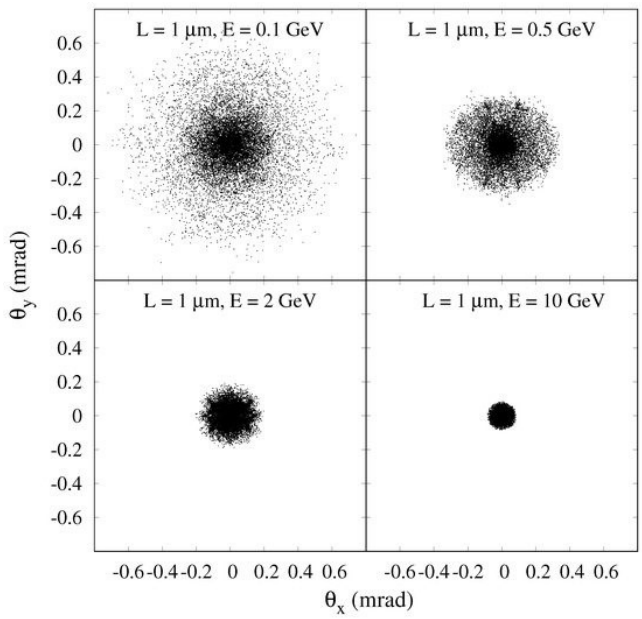

(a)
(b)
c=0
c=1

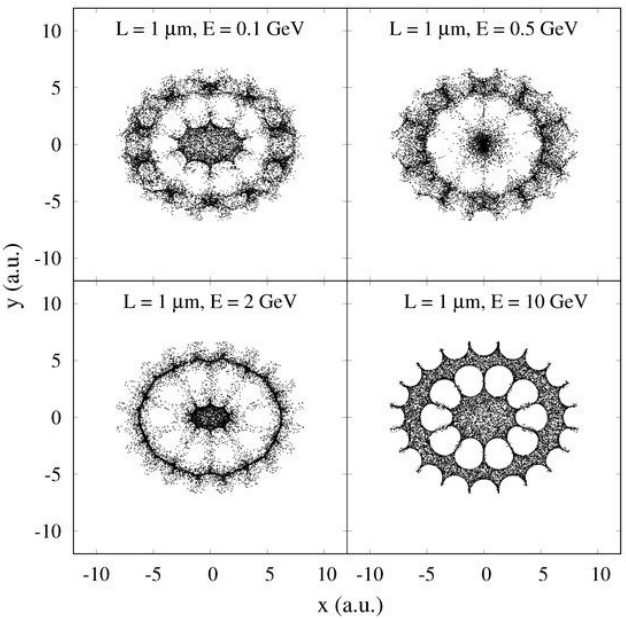

(a)
(b)
(c)
(d)
(e)
(f)

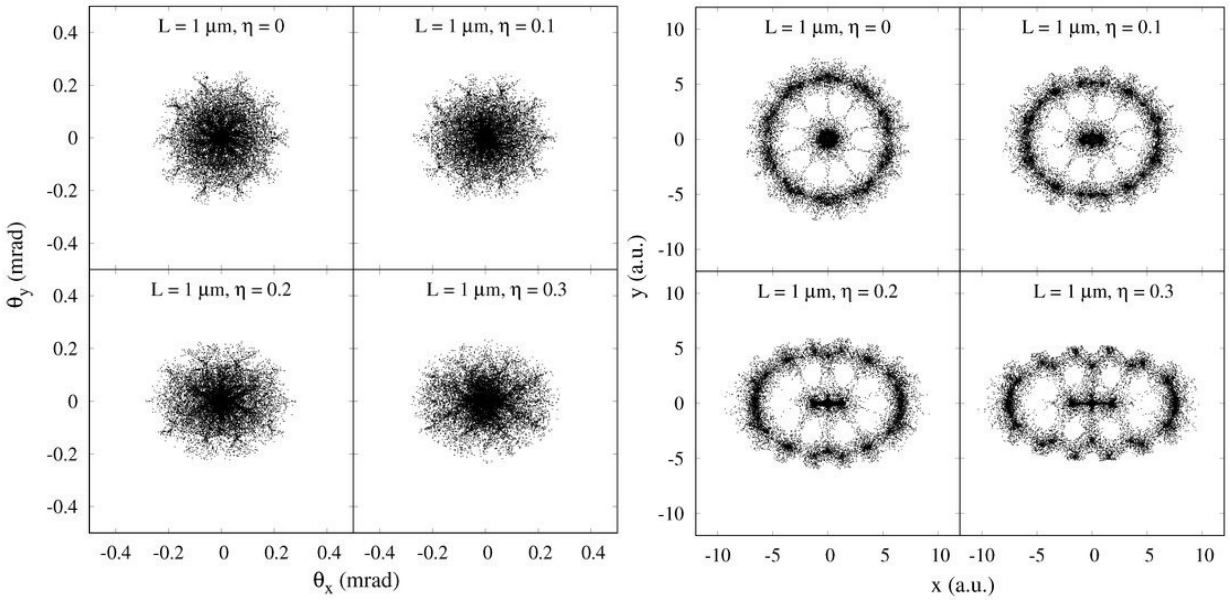

η = 0
η = 0.1
η = 0.2
η = 0.3
y (a.u.)
x (a.u.)

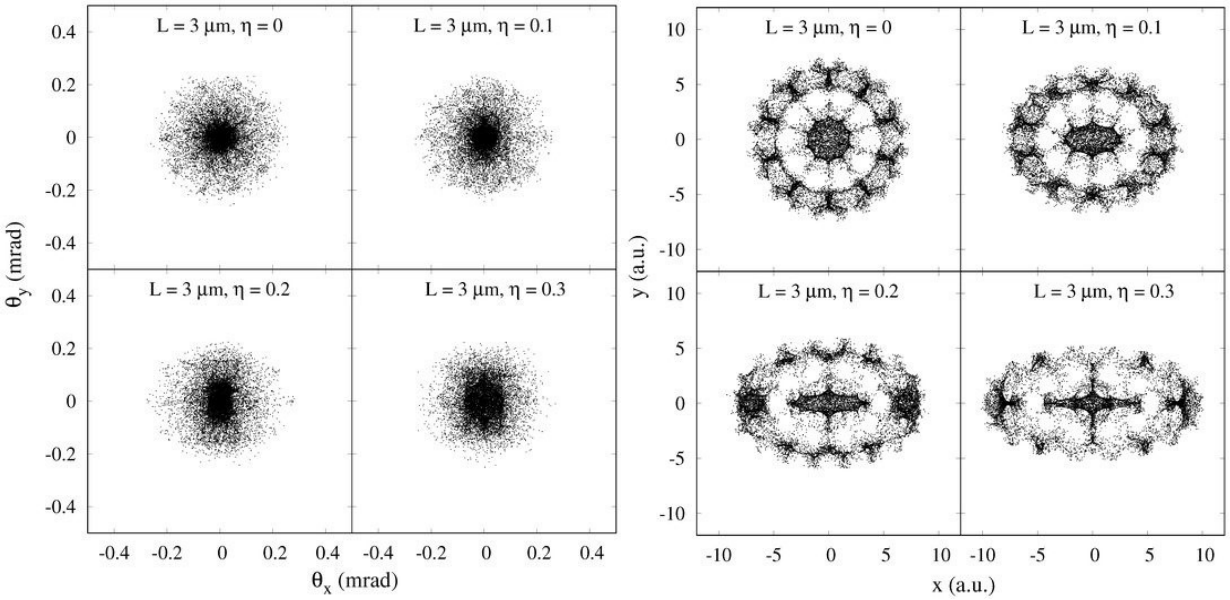

η=0
η=0.1
y (a.u.)
x (a.u.)

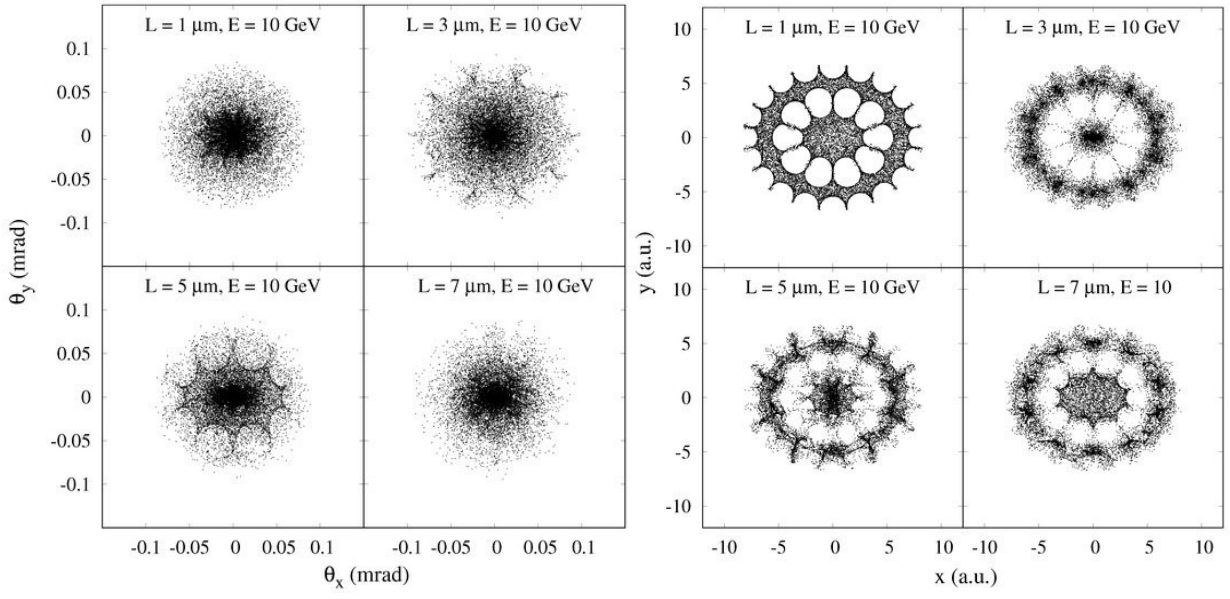

η=0.2
η=0.3
y (a.u.)
x (a.u.)

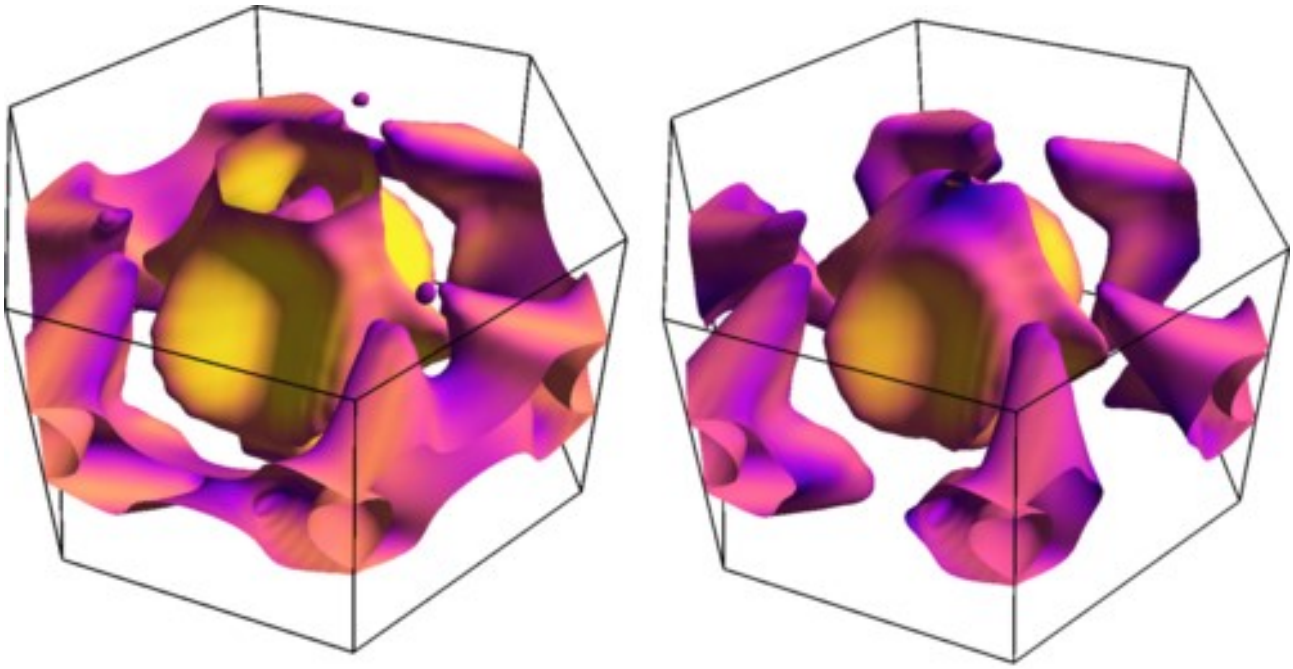

L = 1 μm, E = 0.1 GeV
L = 1 μm, E = 0.5 GeV
L = 1 μm, E = 2 GeV
L = 1 μm, E = 10 GeV
θy (mrad)
θx (mrad)


L = 1 μm, E = 0.1 GeV
L = 1 μm, E = 0.5 GeV
L = 1 μm, E = 2 GeV
L = 1 μm, E = 10 GeV
y (a.u.)
x (a.u.)

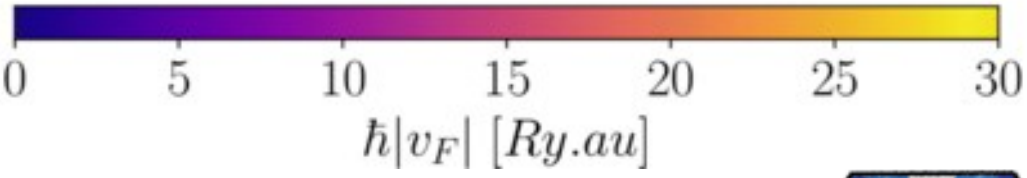

L = 1 μm, η = 0
L = 1 μm, η = 0.1
L = 1 μm, η = 0.2
L = 1 μm, η = 0.3
θy (mrad)
θx (mrad)
y (a.u.)
x (a.u.)

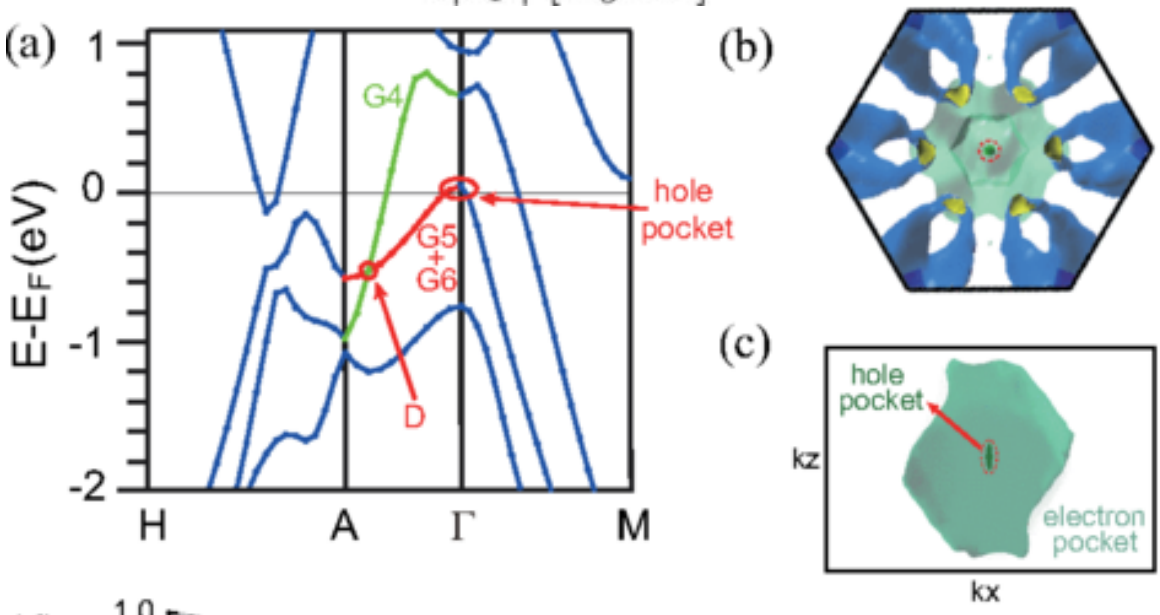

L = 3 μm, η = 0
L = 3 μm, η = 0.1
L = 3 μm, η = 0.2
L = 3 μm, η = 0.3
θy (mrad)
θx (mrad)
y (a.u.)
x (a.u.)

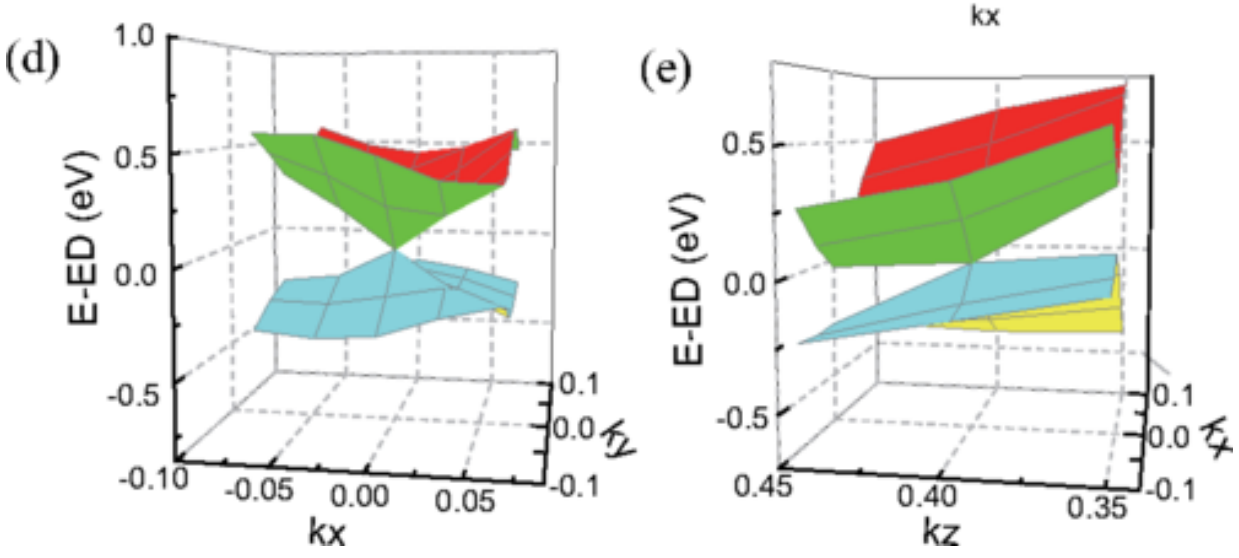

L = 1 μm, E = 10 GeV
L = 3 μm, E = 10 GeV
L = 5 μm, E = 10 GeV
L = 7 μm, E = 10 GeV
L = 1 μm, E = 10 GeV
L = 3 μm, E = 10 GeV
L = 5 μm, E = 10 GeV
L = 7 μm, E = 10
θy (mrad)
θx (mrad)
y (a.u.)
x (a.u.)

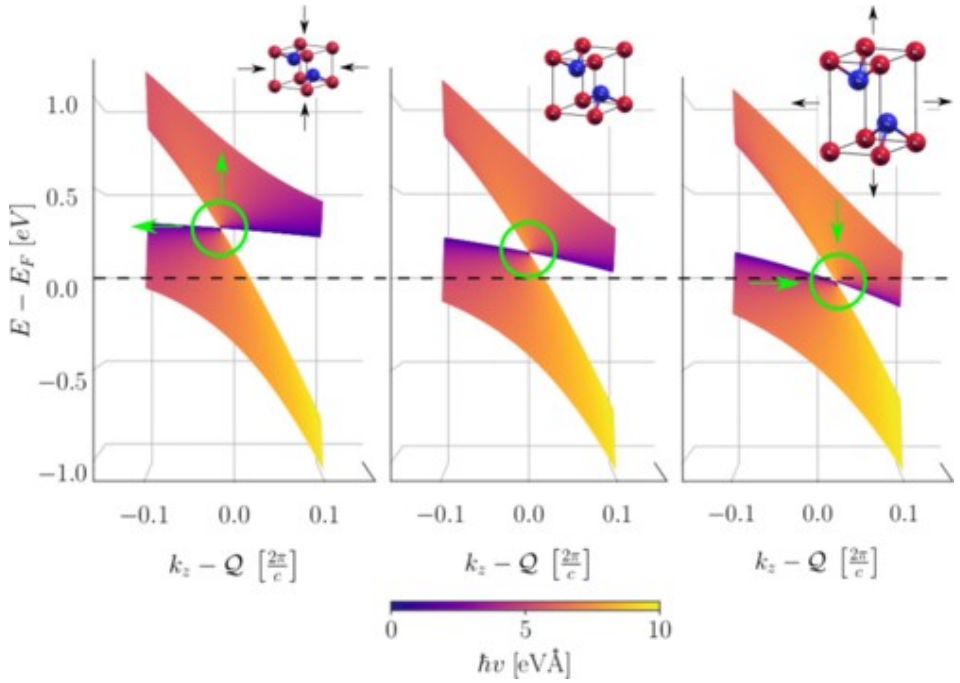


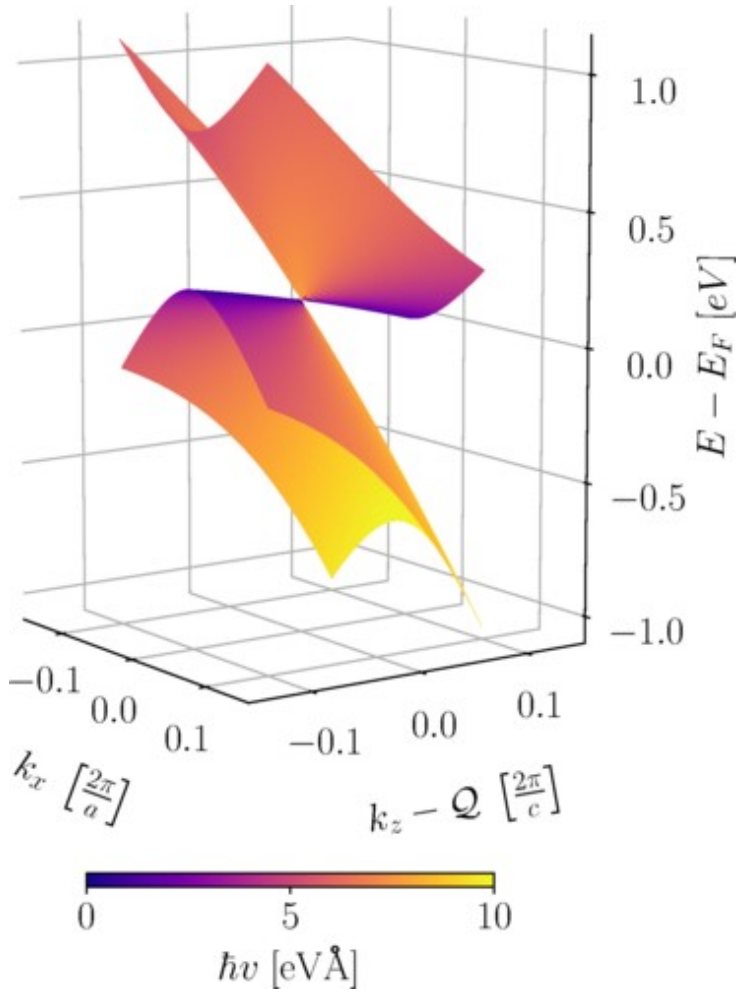
(a) $\eta = (-0.02, -0.02, -0.02)$ (b) $\eta = (0.02, 0.02, 0.02)$



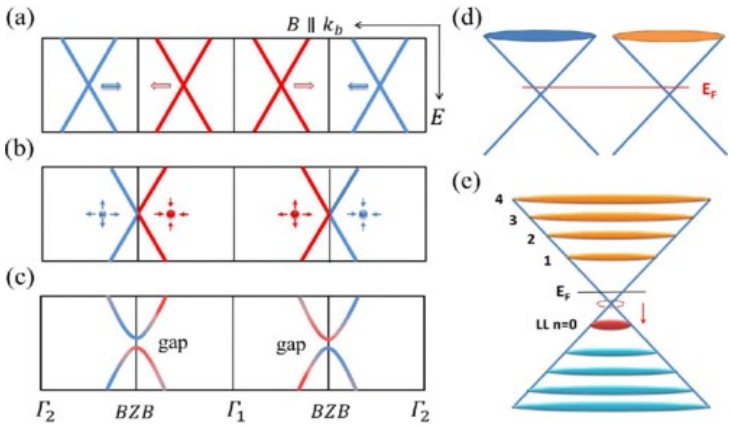


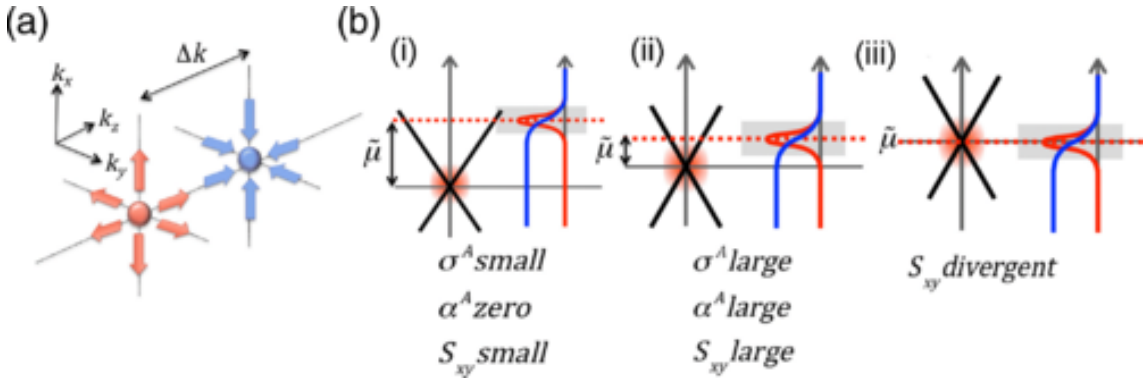


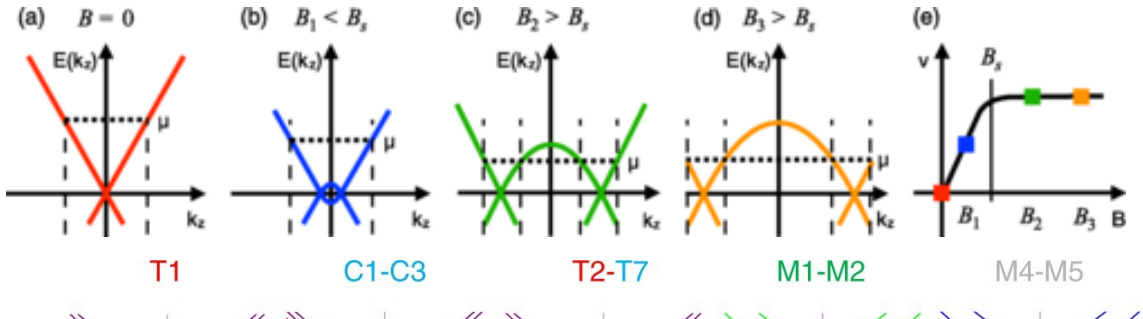

1.0
0.5
0.0
−0.5
−1.0
$E - E_F$ [eV]
−0.1
0.0
0.1
$k_z - \mathcal{Q}$ $\left[\frac{2\pi}{c}\right]$
0
5
10
$\hbar v$ [eVÅ]

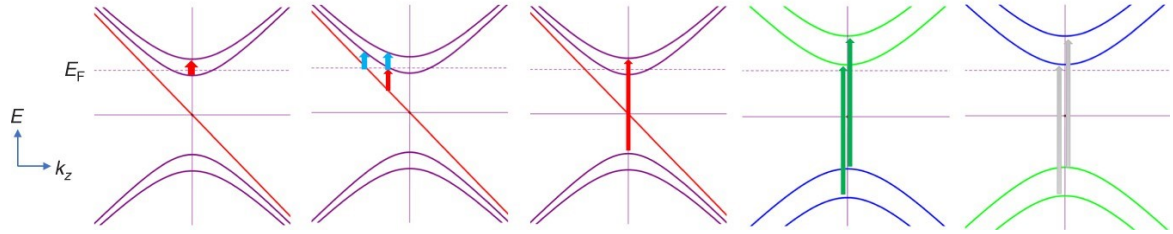

1.0
0.5
0.0
−0.5
−1.0
$E - E_F$ [eV]
−0.1
0.0
0.1
k_x $\left[\frac{2\pi}{a}\right]$
$k_z - \mathcal{Q}$ $\left[\frac{2\pi}{c}\right]$
0
5
10
$\hbar v$ [eVÅ]

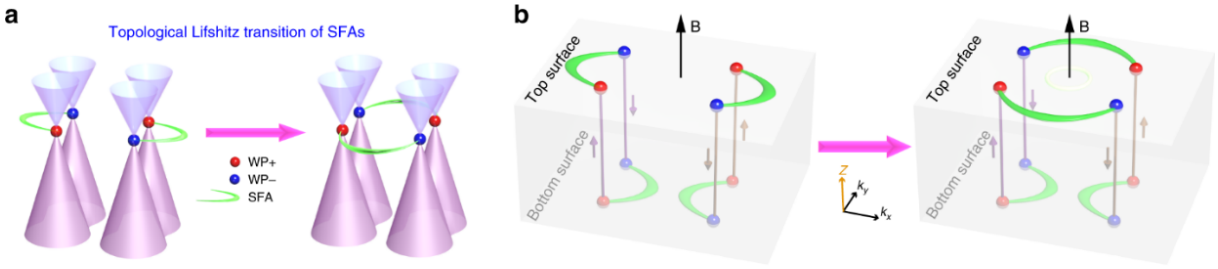
(a)
(b)
(c)

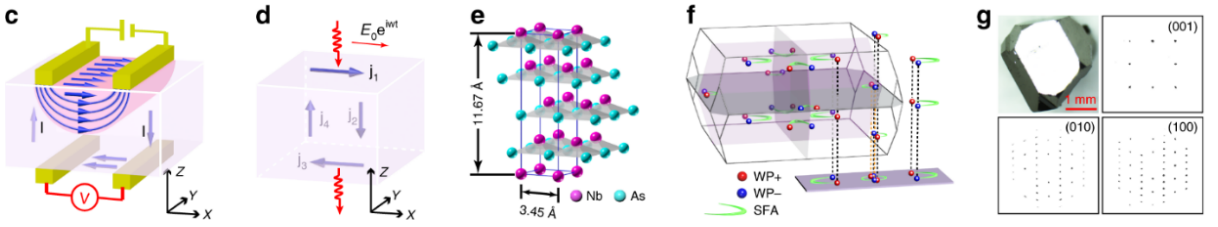

(a)
B ∥ k_b
E
(b)
(c)
gap
gap
Γ2
BZB
Γ1
BZB
Γ2
(d)
E_F
(c)
4
3
2
1
E_F
LL n=0

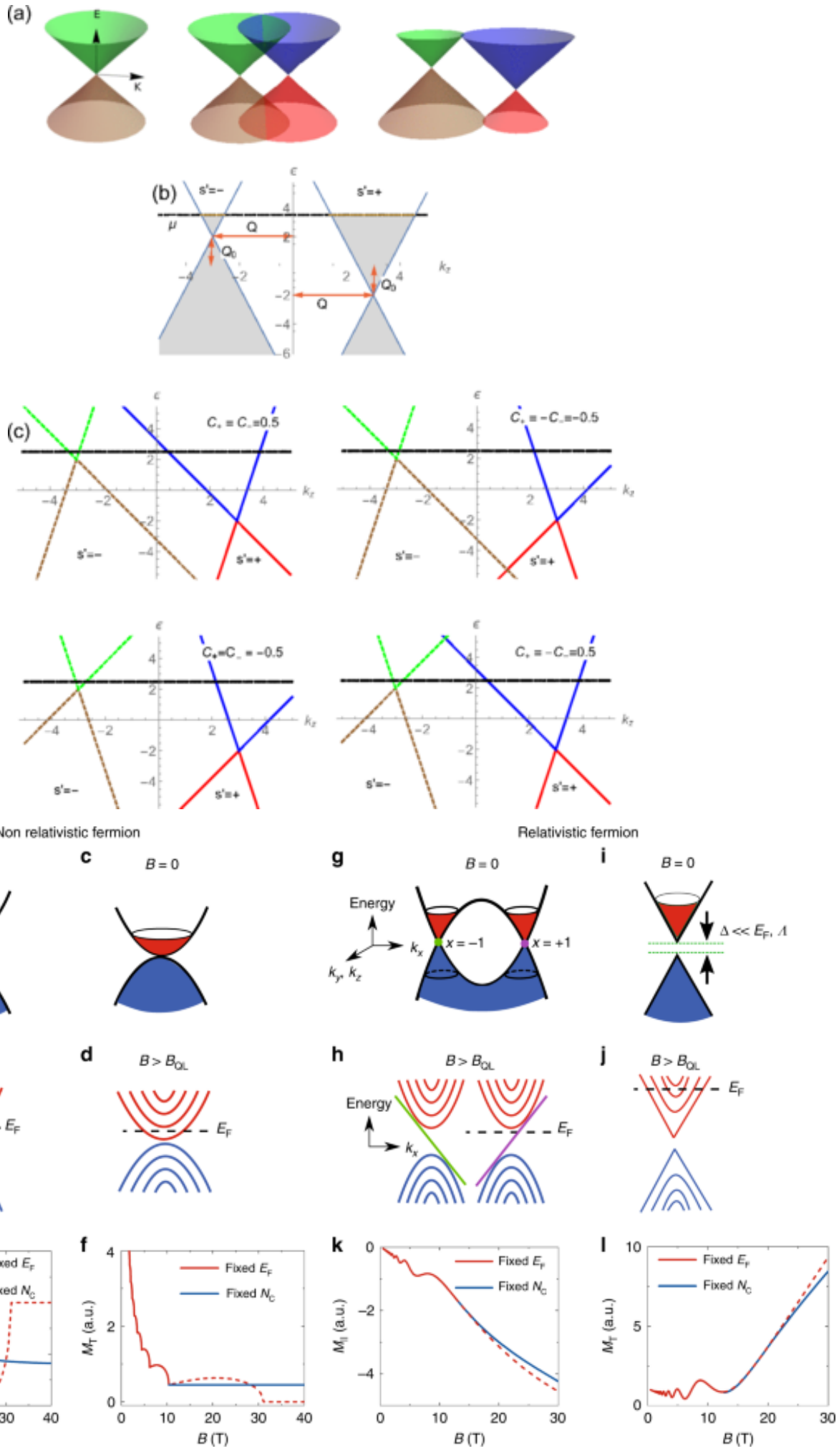

(a)
Δk
k_x
k_z
k_y
(b)
(i)
(ii)
(iii)
μ̃
μ̃
μ̃
σ^A small
α^A zero
S_xy small
σ^A large
α^A large
S_xy large
S_xy divergent

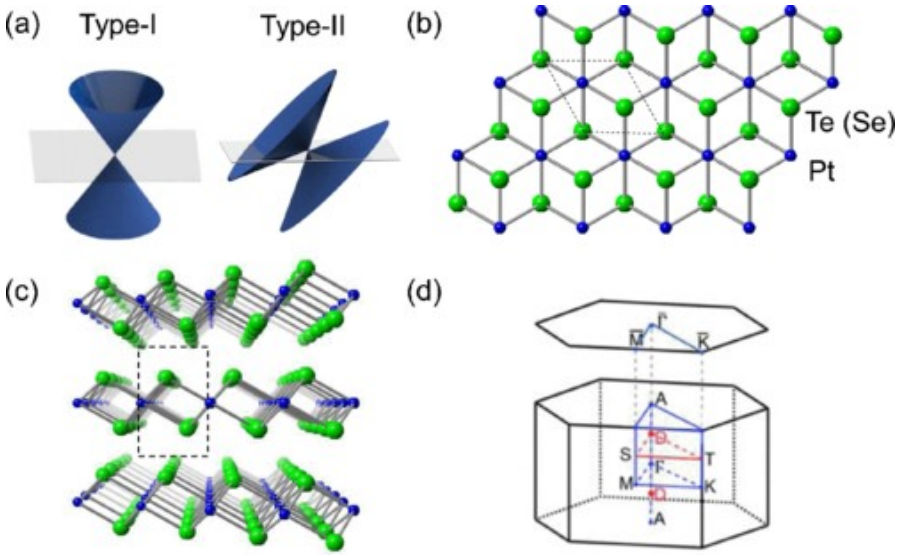

(a) B = 0
(b) B1 < Bs
(c) B2 > Bs
(d) B3 > Bs
(e)
E(kz)
μ
kz
v
Bs
B1
B2
B3
B
T1
C1-C3
T2-T7
M1-M2
M4-M5

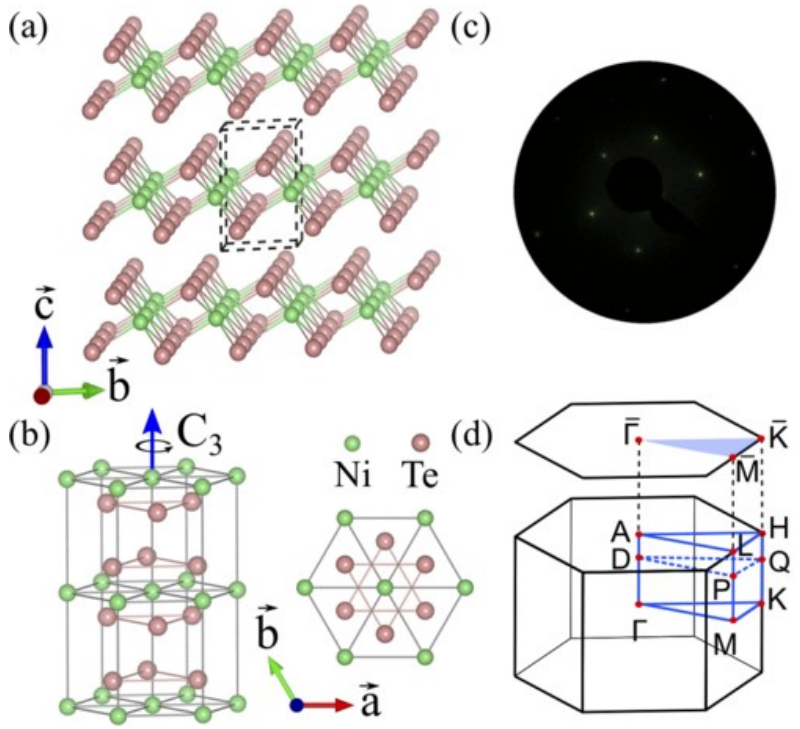

E_F
E
k_z

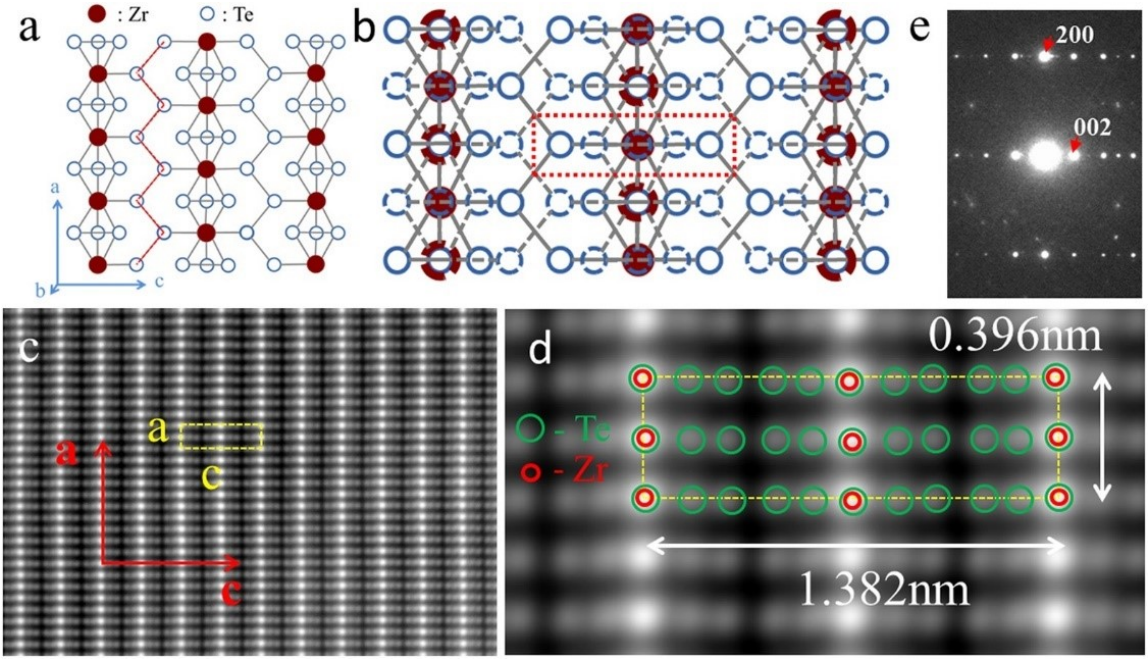

a
Topological Lifshitz transition of SFAs
WP+
WP−
SFA
b
B
Top surface
Bottom surface
B
Top surface
Bottom surface

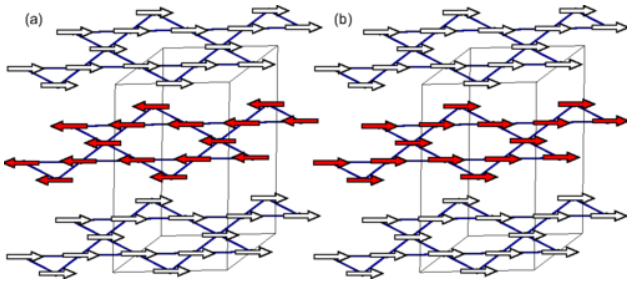

c
I
I
V
Z
Y
X
d
E0e^iwt
j1
j4
j2
j3
Z
Y
X
e
11.67 Å
3.45 Å
Nb
As
f
WP+
WP−
SFA
g
1 mm
(001)
(010)
(100)

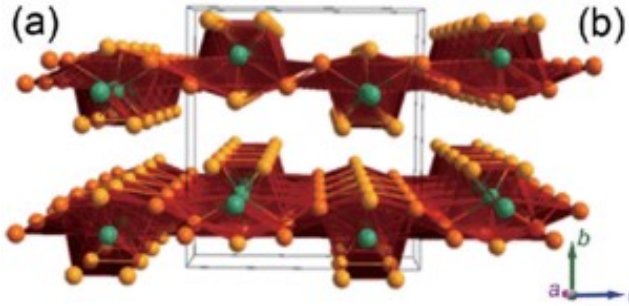

(a)
E
K
(b)
s'=−
s'=+
μ
Q
Q0
kz
(c)
C+ = C−=0.5
C+ = −C−=−0.5
C+=C− = −0.5
C+ = −C−=0.5
s'=−
s'=+
Non relativistic fermion
Relativistic fermion
a
B = 0
Energy
kx
ky, kz
c
B = 0
g
B = 0
Energy
kx
x = −1
x = +1
ky, kz
i
B = 0
Δ << EF, Λ
b
B > BQL
Energy
EF
kx
d
B > BQL
EF
h
B > BQL
Energy
kx
EF
j
B > BQL
EF
e
M∥ (a.u.)
Fixed EF
Fixed NC
B (T)
f
MT (a.u.)
Fixed EF
Fixed NC
B (T)
k
M∥ (a.u.)
Fixed EF
Fixed NC
B (T)
l
MT (a.u.)
Fixed EF
Fixed NC
B (T)

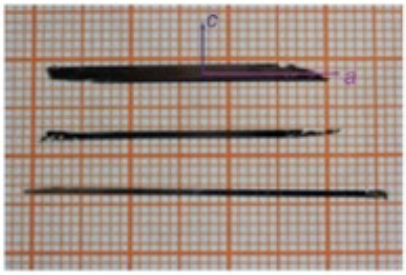

(a)
Type-I
Type-II
(b)
Te (Se)
Pt
(c)
(d)
Γ
M
K
A
H
L
S
F
T
K
M
Γ
A

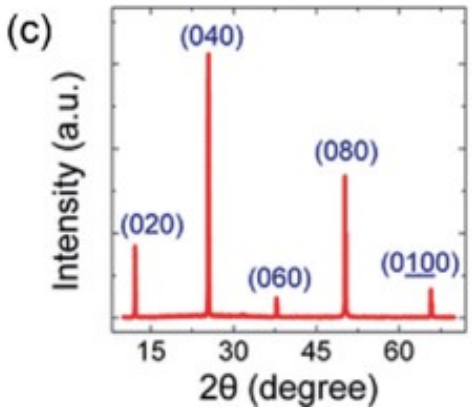

(a)
(c)
c
b
(b)
C3
Ni
Te
b
a
(d)
Γ
K
M
A
H
D
L
Q
P
K
Γ
M

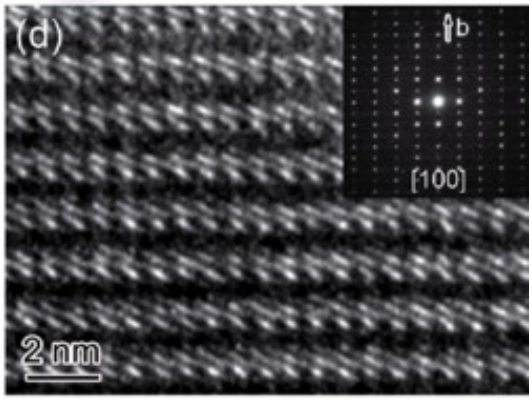

a
: Zr
: Te
a
b
c
b
e
200
002
c
a
a
c
c
d
0.396nm
- Te
- Zr
1.382nm

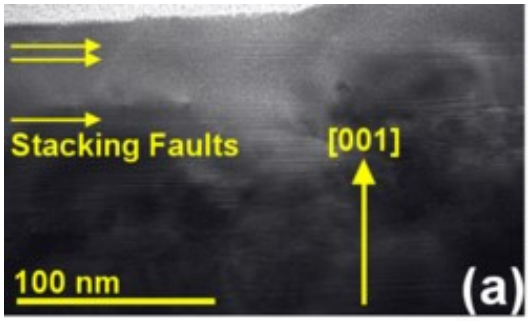

(a)
(b)

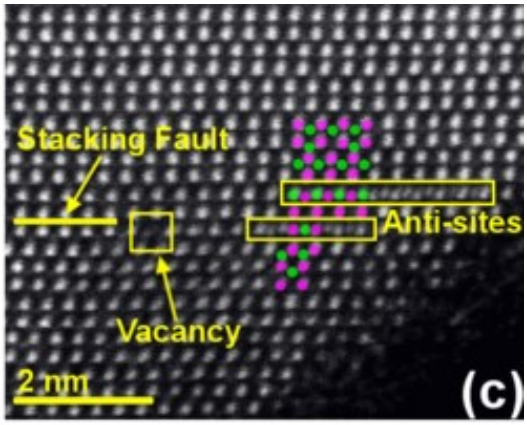

(a)
b
a
c

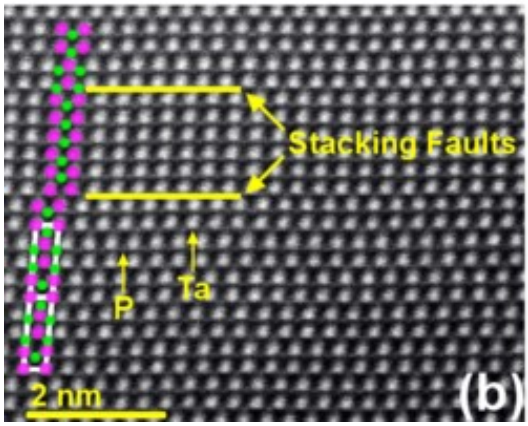

(b)
c
a

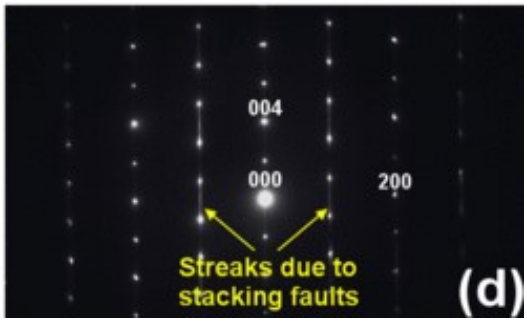

(c)
Intensity (a.u.)
(040)
(080)
(020)
(060)
(0100)
15
30
45
60
2θ (degree)

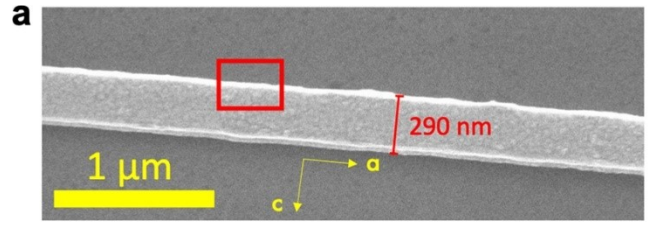

(d)
b
[100]
2 nm

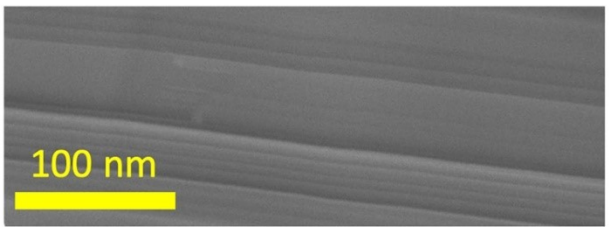

Stacking Faults
[001]
100 nm
(a)

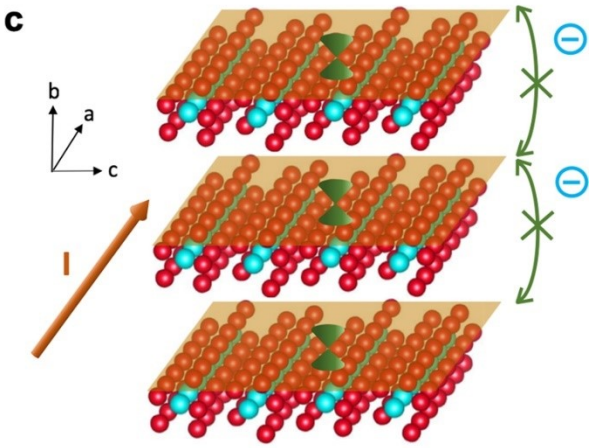

Stacking Fault
Anti-sites
Vacancy
2 nm
(c)

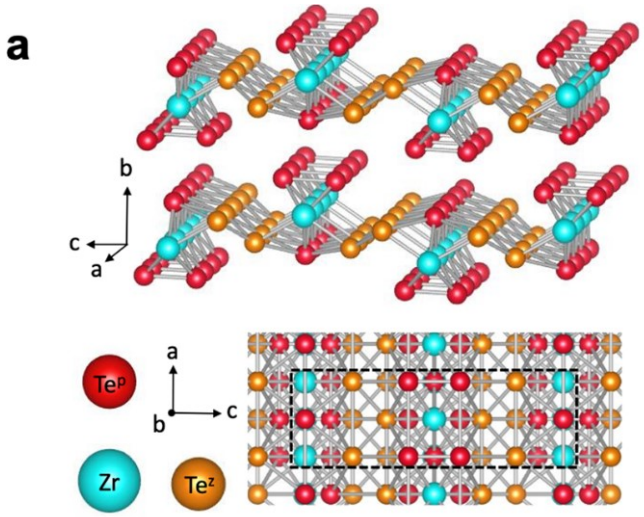

Stacking Faults
P
Ta
2 nm
(b)

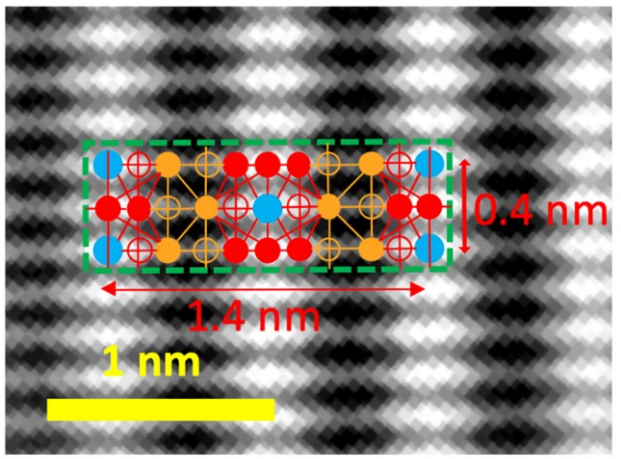

004
000
200
Streaks due to
stacking faults
(d)

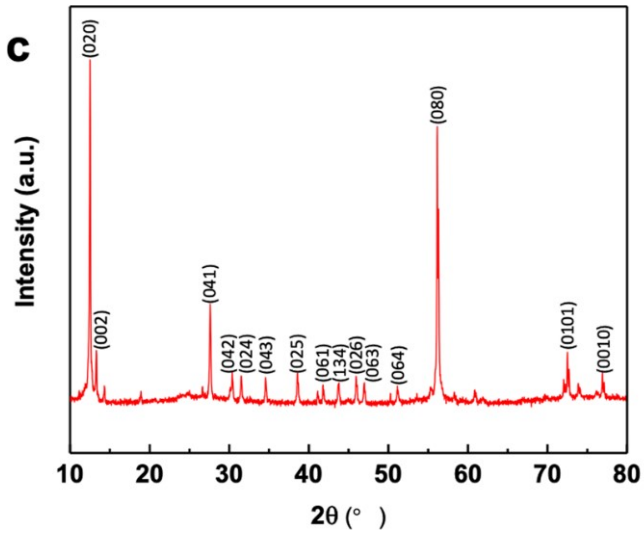

a
290 nm
1 μm
a
c

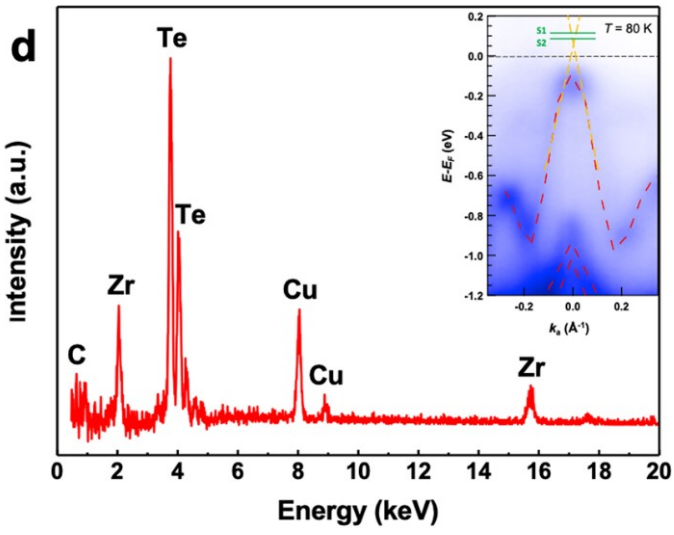

b
100 nm

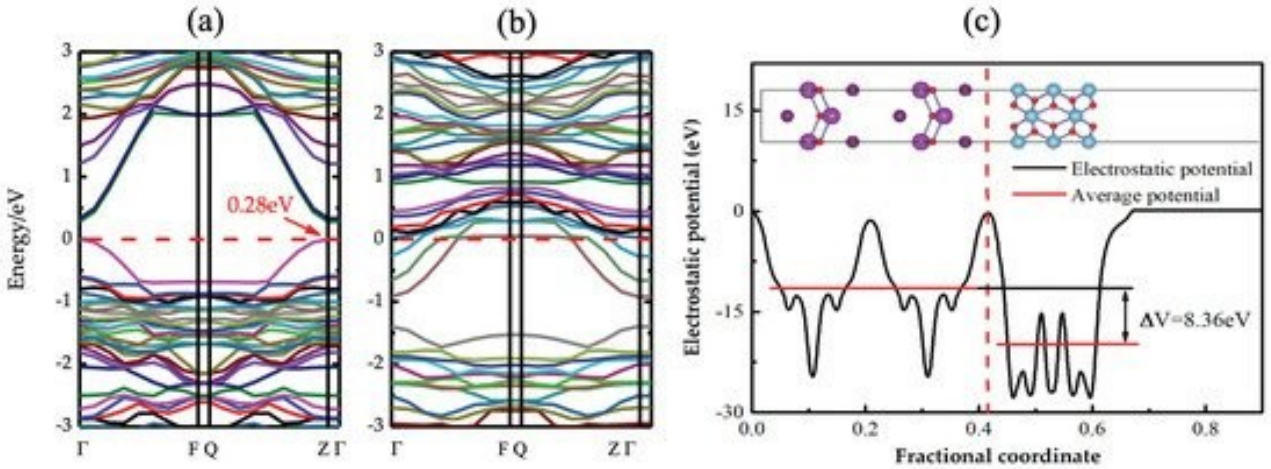

c
b
a
c
I

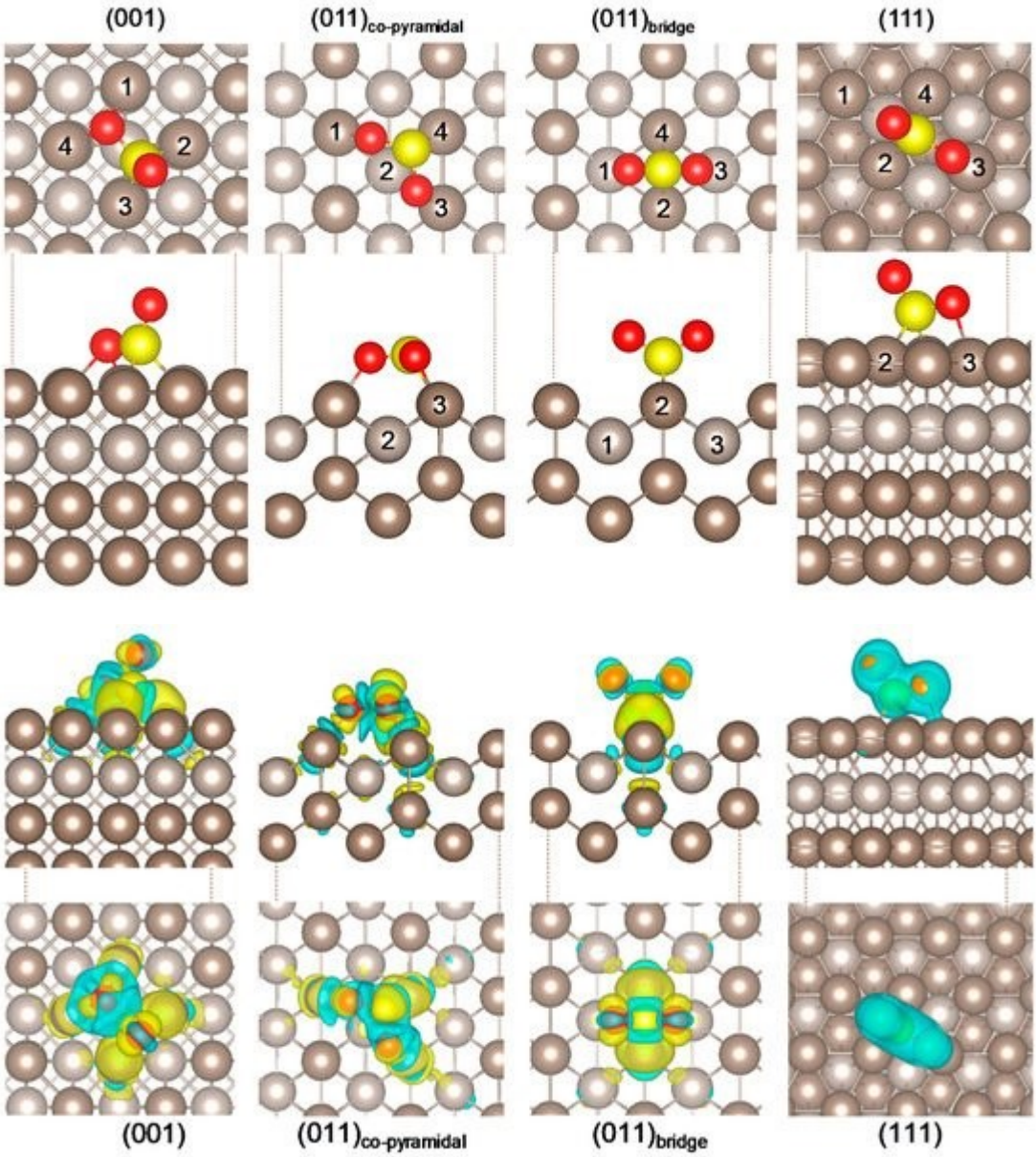

a
b
c
a
Te^P
Zr
Te^Z
a
b
c

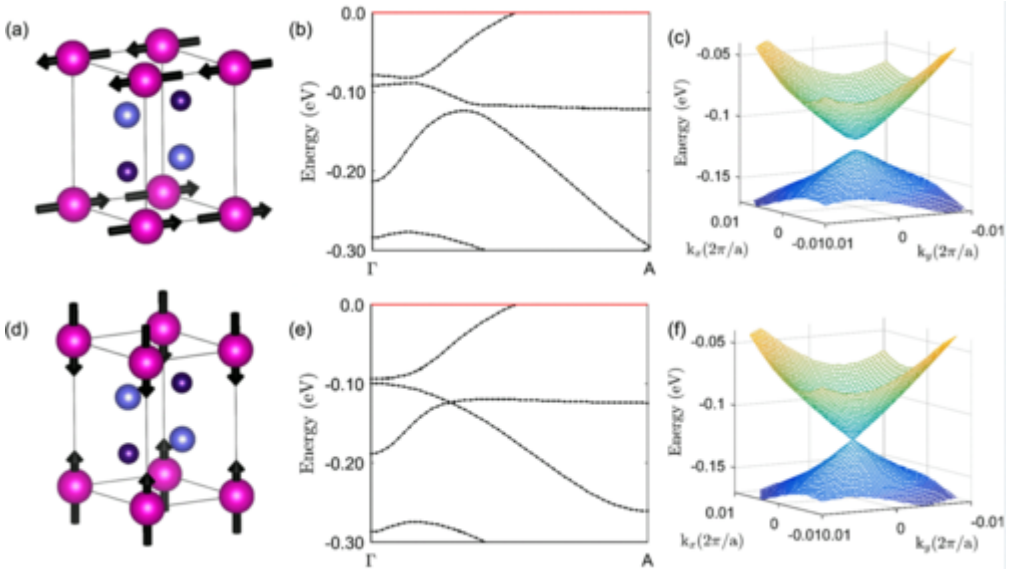

b
0.4 nm
1.4 nm
1 nm

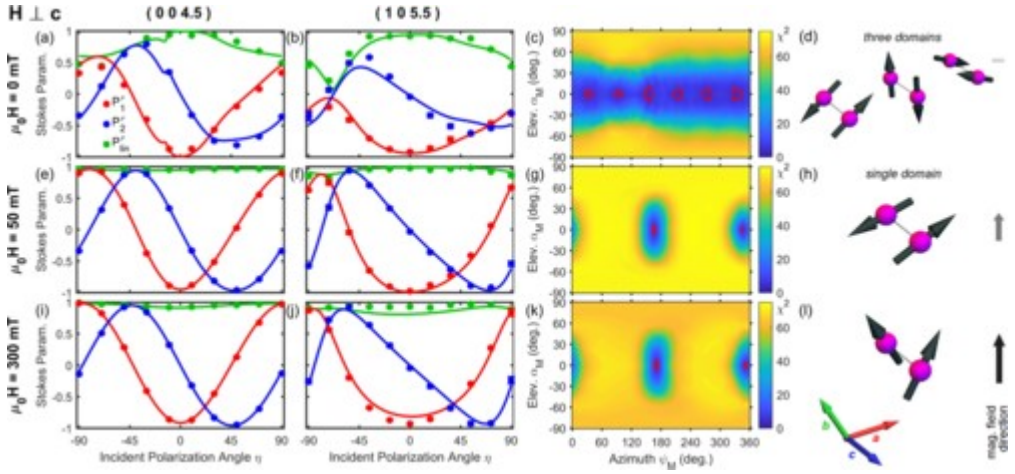

c
Intensity (a.u.)
(020)
(002)
(041)
(042)
(024)
(043)
(025)
(061)
(134)
(026)
(063)
(064)
(080)
(0101)
(0010)
10
20
30
40
50
60
70
80
2θ (°)

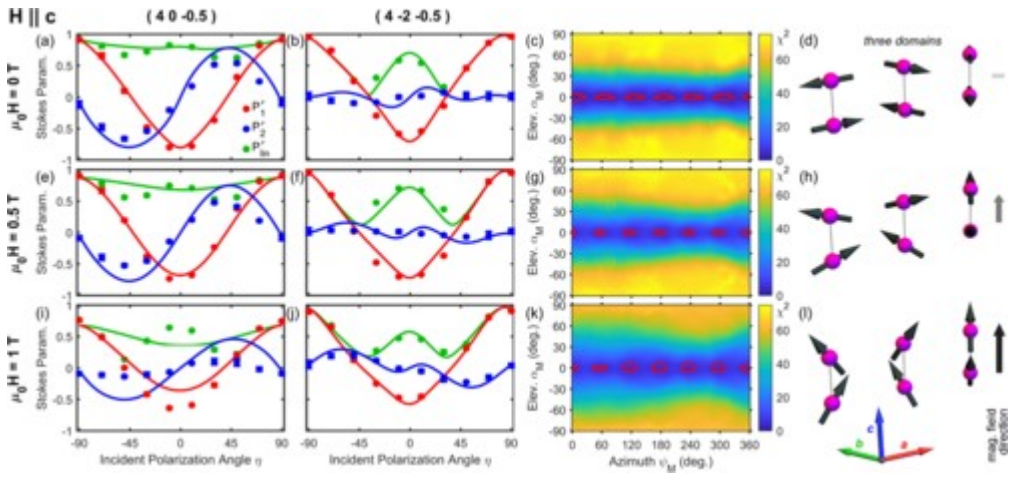

d
Intensity (a.u.)
Te
Te
Zr
Cu
Cu
C
Zr
0
2
4
6
8
10
12
14
16
18
20
Energy (keV)
T = 80 K
S1
S2
E-E_F (eV)
k_x (Å^-1)

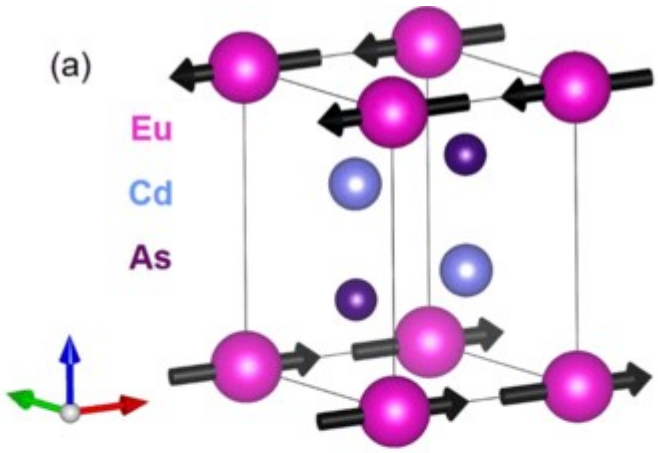

(a)
(b)
(c)
Energy/eV
0.28eV
Γ
FQ
ZΓ
Electrostatic potential (eV)
Electrostatic potential
Average potential
ΔV=8.36eV
Fractional coordinate

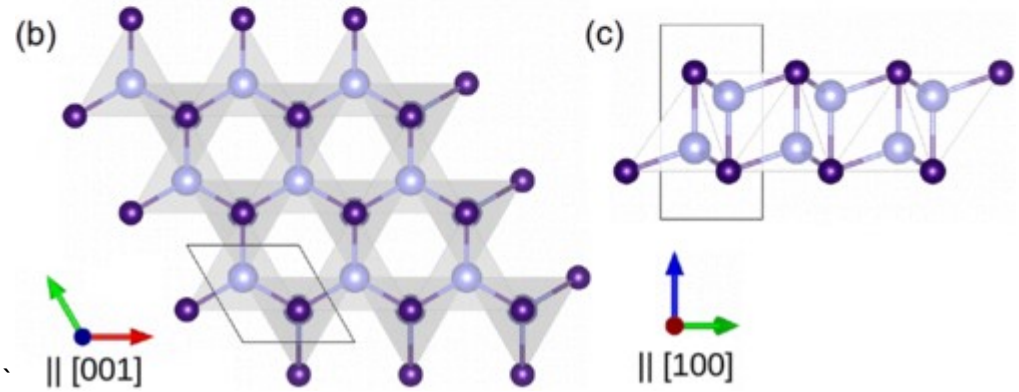

(001)
(011)co-pyramidal
(011)bridge
(111)
1
2
3
4
(001)
(011)co-pyramidal
(011)bridge
(111)

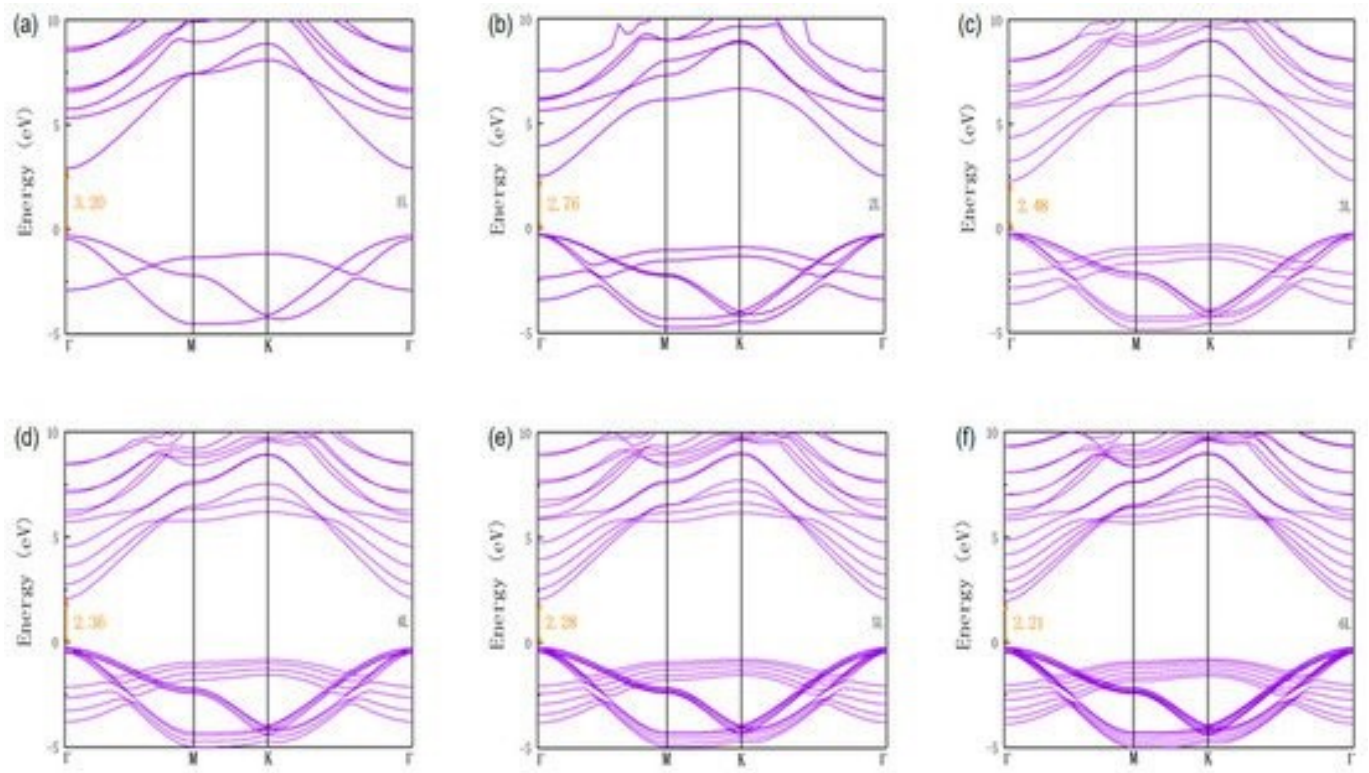

(a)
(b)
(c)
(d)
(e)
(f)
Energy (eV)
0.0
-0.10
-0.20
-0.30
Γ
A
-0.05
-0.1
-0.15
0.01
0
-0.01
$k_x(2\pi/a)$
$k_y(2\pi/a)$

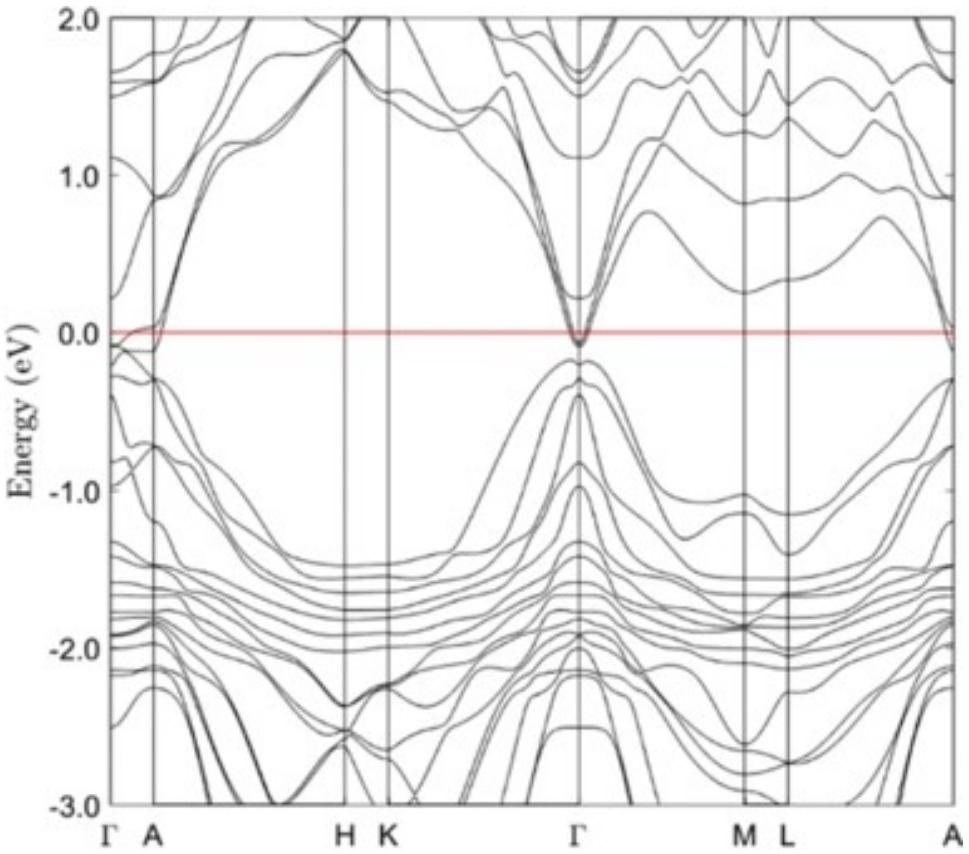

H ⊥ c
(0 0 4.5)
(1 0 5.5)
μ0H = 0 mT
μ0H = 50 mT
μ0H = 300 mT
Stokes Param.
Incident Polarization Angle η
Elev. αM (deg.)
Azimuth ψM (deg.)
three domains
single domain
mag. field direction

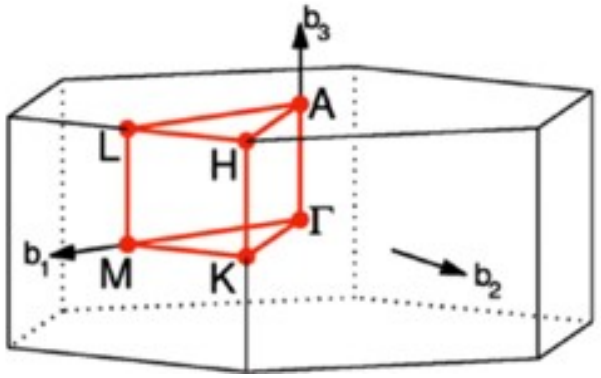

H || c
(4 0 -0.5)
(4 -2 -0.5)
μ0H = 0 T
μ0H = 0.5 T
μ0H = 1 T
Stokes Param.
Incident Polarization Angle η
Elev. αM (deg.)
Azimuth ψM (deg.)
three domains
mag. field direction

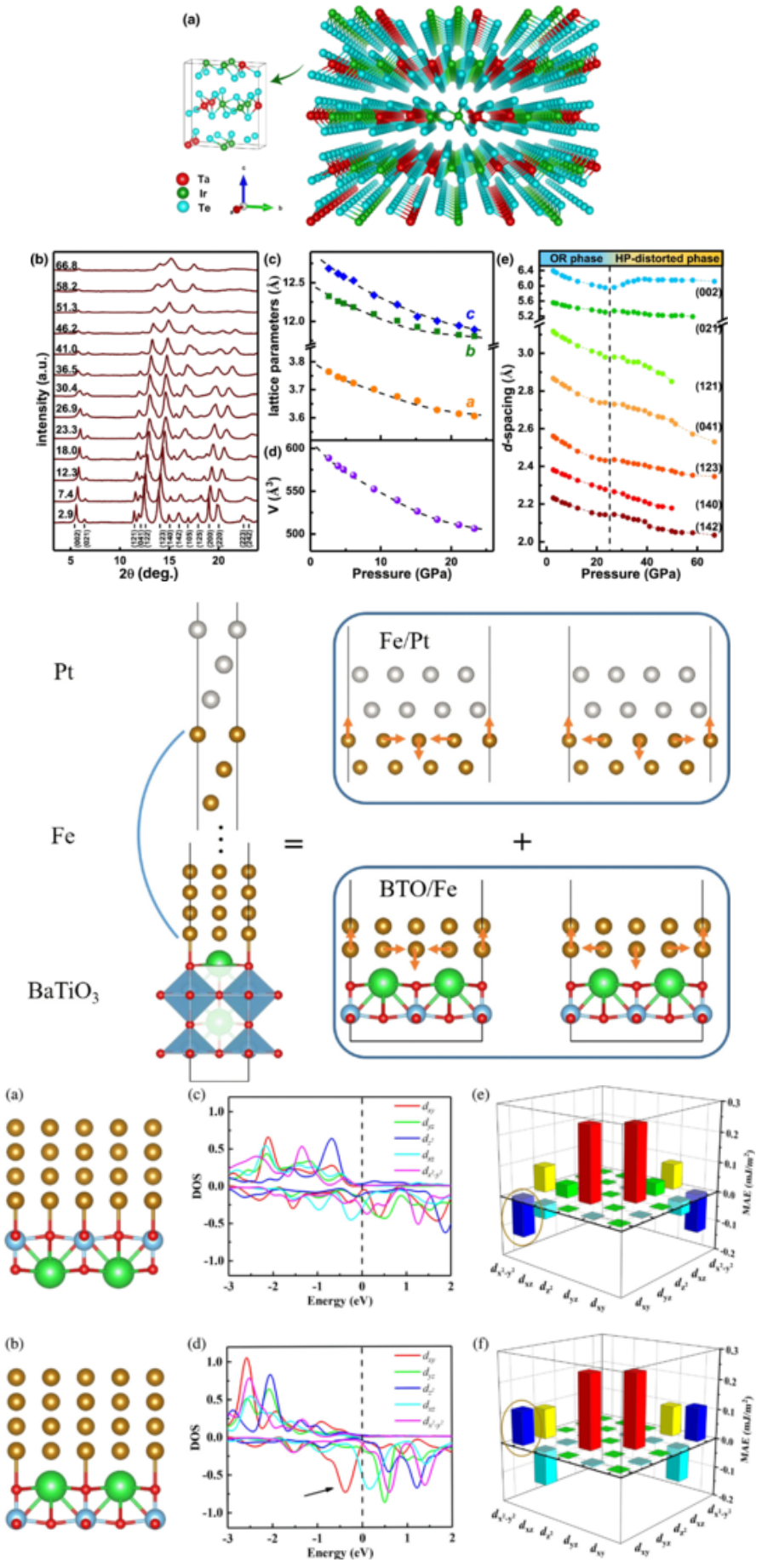

(a)
Eu
Cd
As

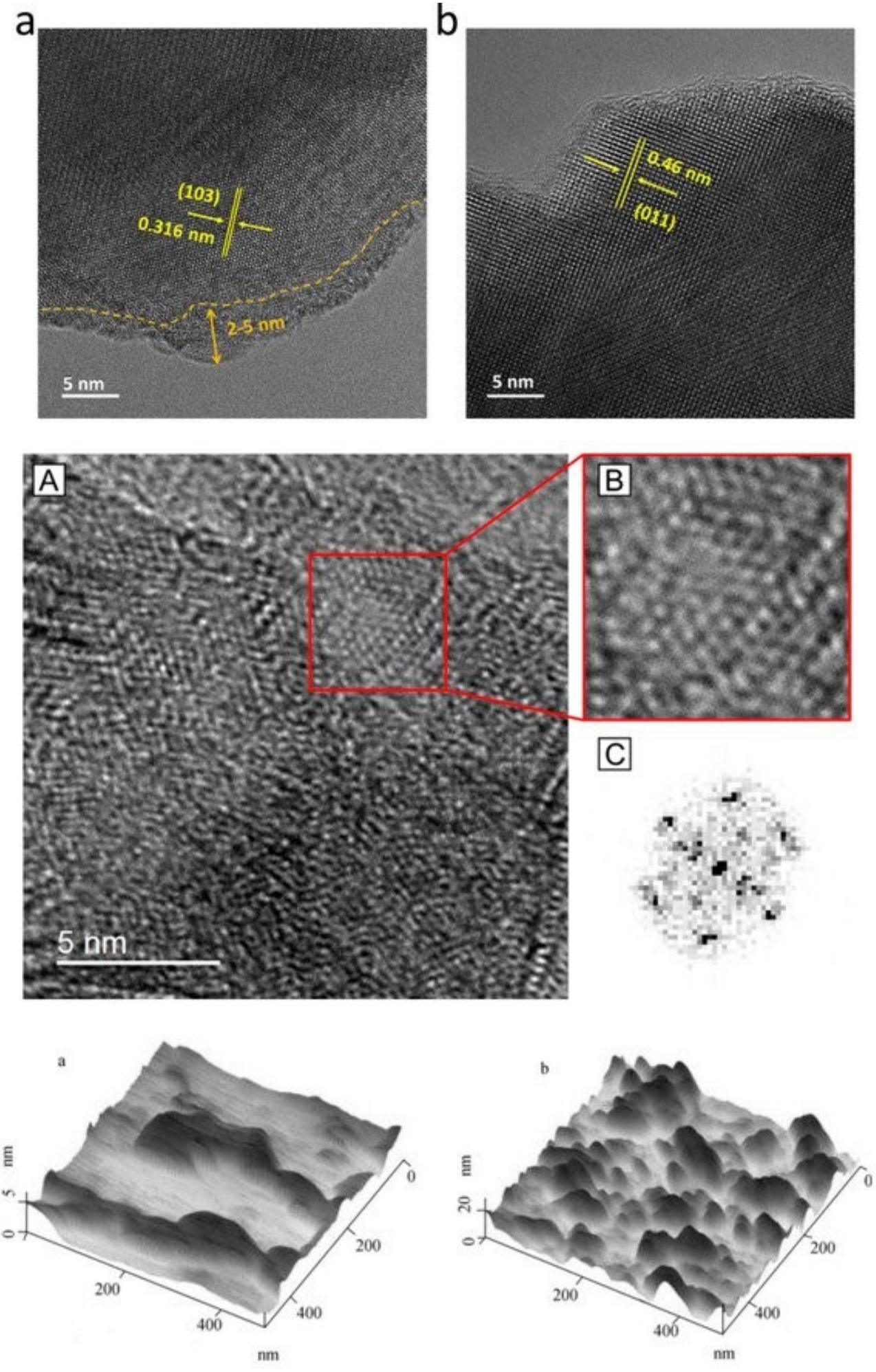

(b)
|| [001]
(c)
|| [100]

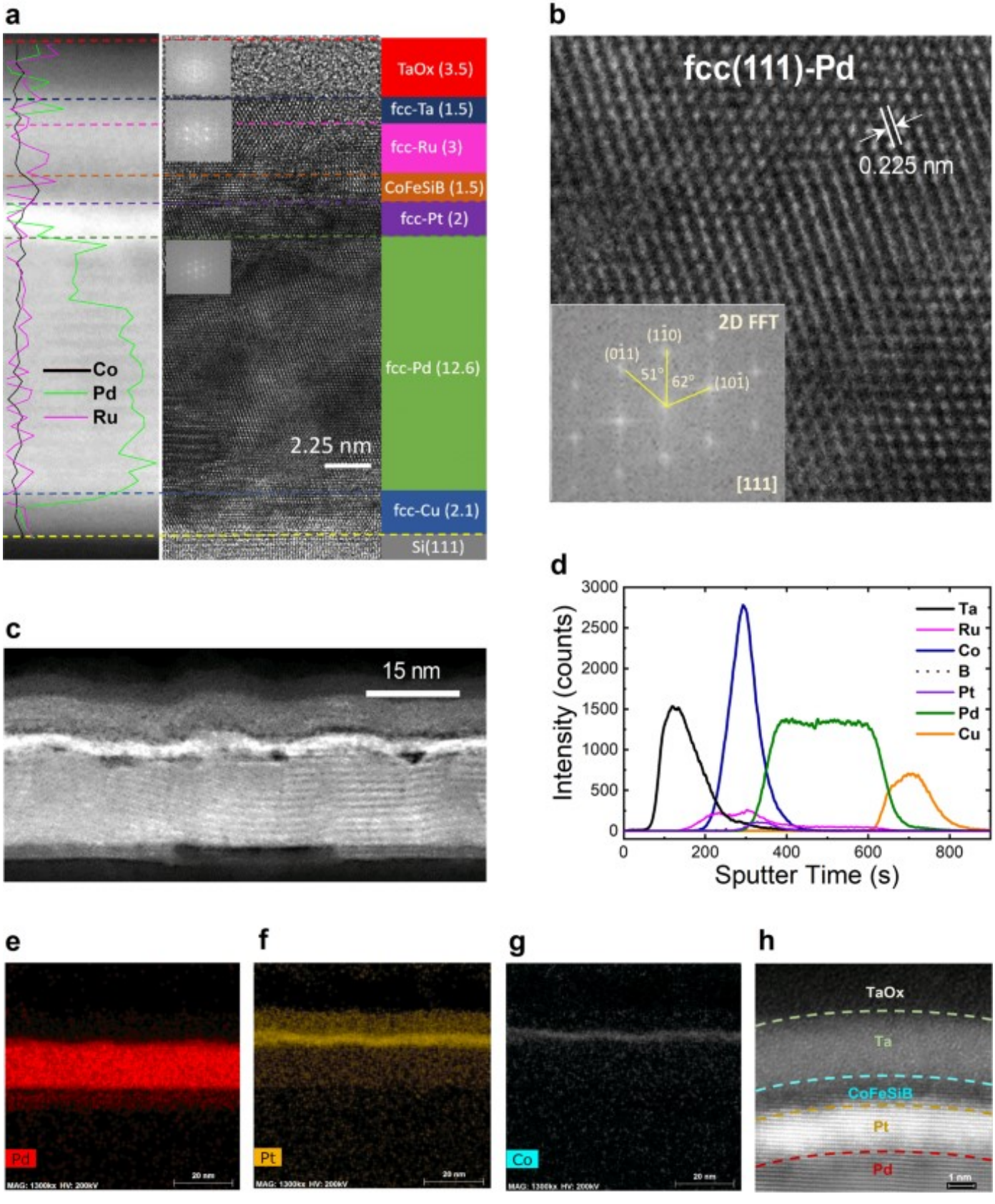

(a)
(b)
(c)
(d)
(e)
(f)
Energy (eV)
Γ
M
K
Γ

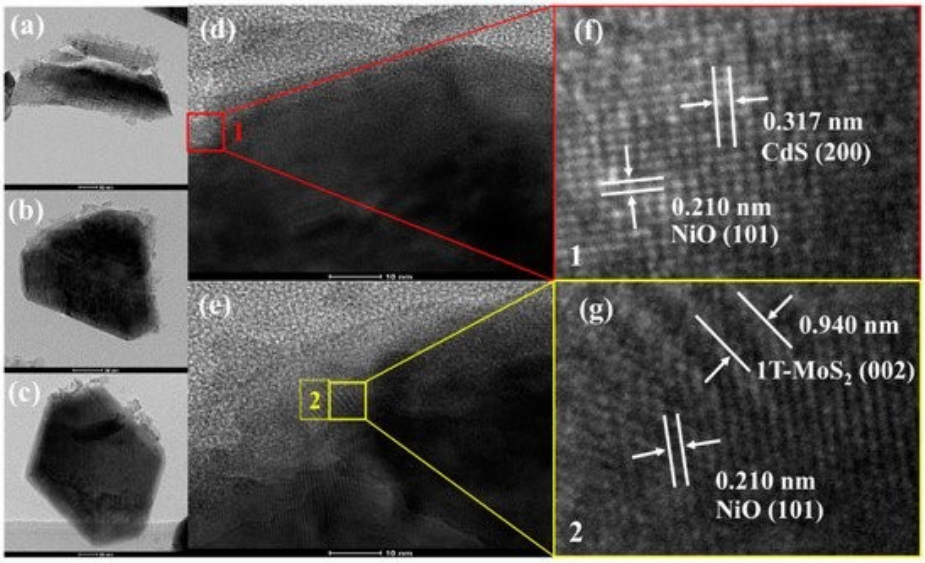

2.0
1.0
0.0
-1.0
-2.0
-3.0
Energy (eV)
Γ A H K Γ M L A

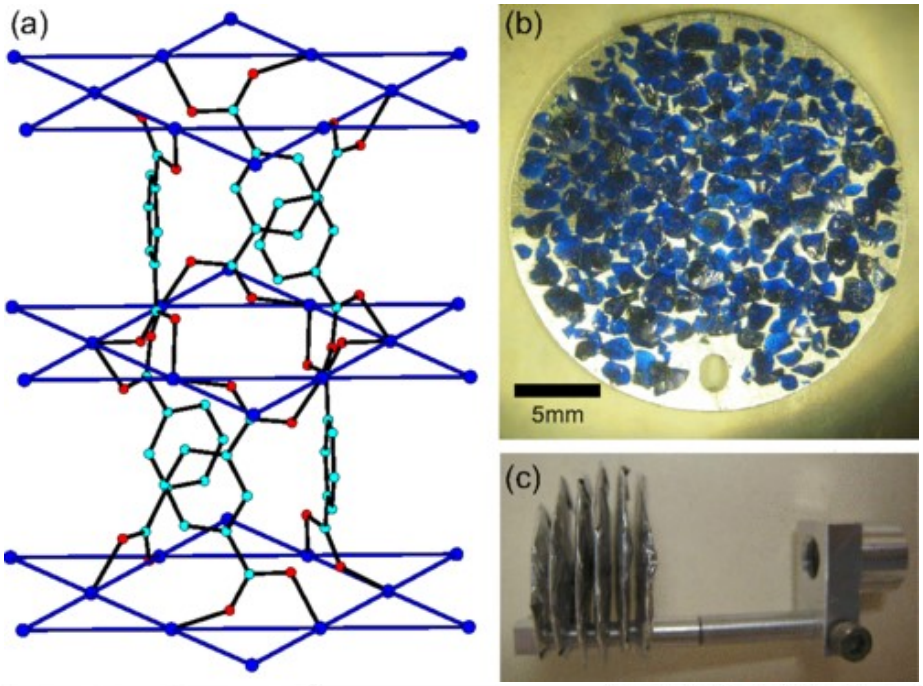

b3
A
L
H
Γ
b1
M
K
b2

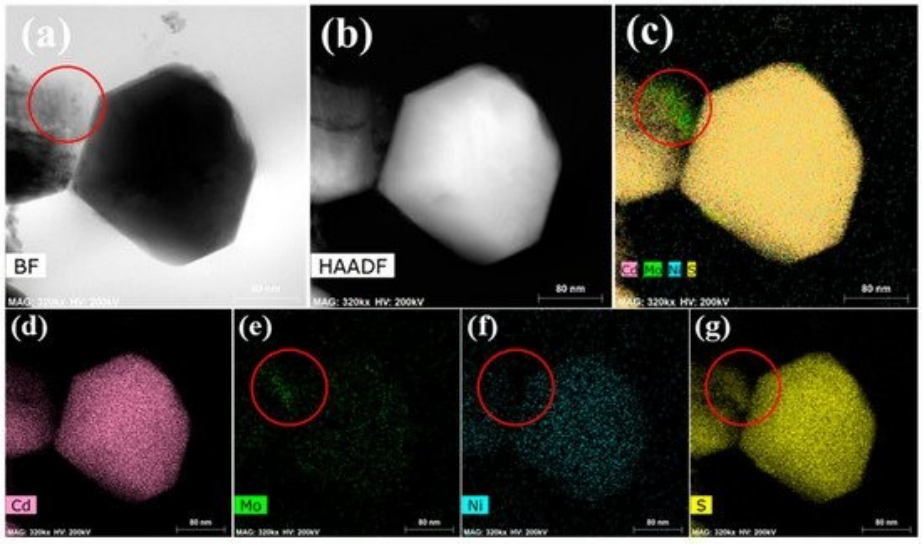

(a)
Ta
Ir
Te
(b)
66.8
58.2
51.3
46.2
41.0
36.5
30.4
26.9
23.3
18.0
12.3
7.4
2.9
Intensity (a.u.)
2θ (deg.)
(c)
lattice parameters (Å)
c
b
a
(d)
V (Å³)
Pressure (GPa)
(e)
OR phase
HP-distorted phase
d-spacing (Å)
(002)
(021)
(121)
(041)
(123)
(140)
(142)
Pressure (GPa)
Pt
Fe
BaTiO3
Fe/Pt
BTO/Fe
(a)
(b)
(c)
(d)
(e)
(f)
DOS
Energy (eV)
MAE (mJ/m²)

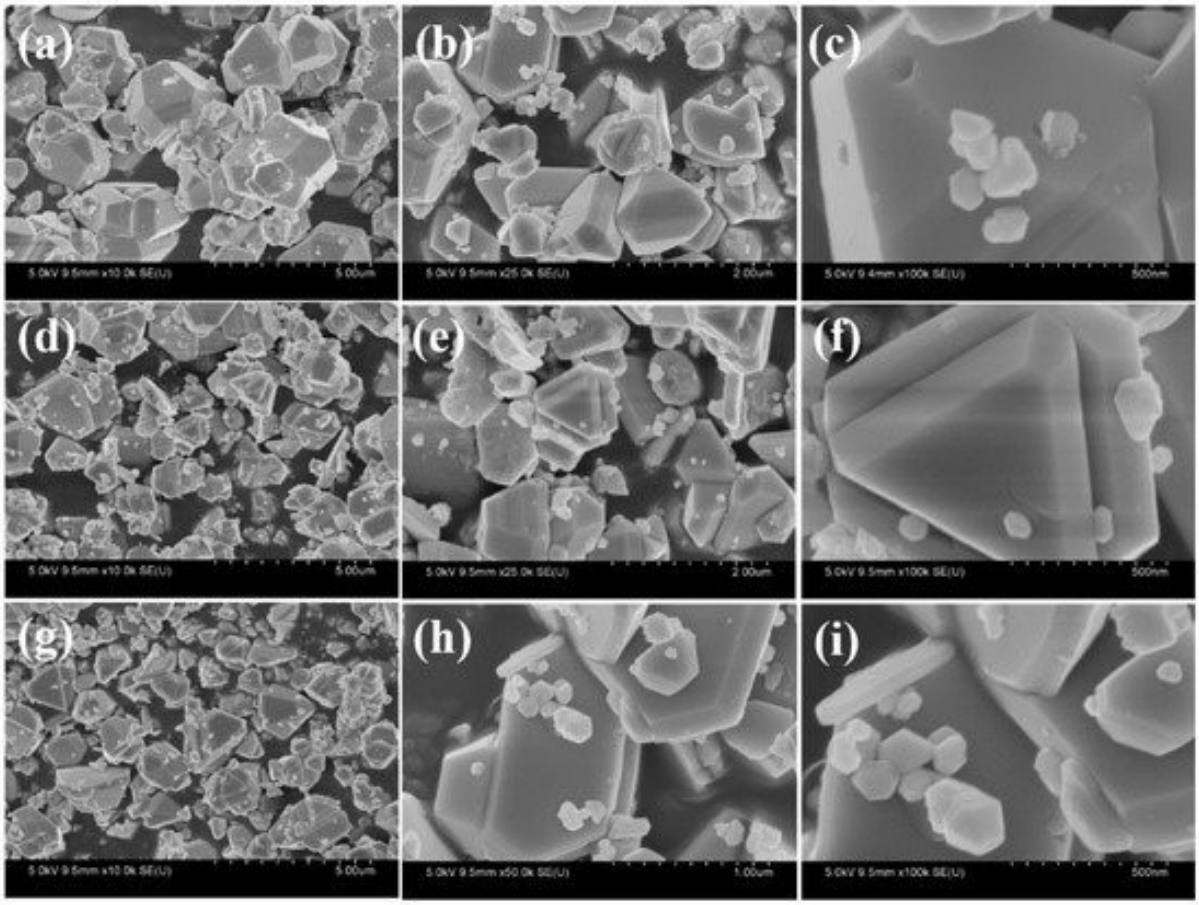

a
(103)
0.316 nm
2.5 nm
5 nm
b
0.46 nm
(011)
5 nm
A
B
C
5 nm
a
nm
5
0
200
400
nm
0
200
400
b
nm
20
0
200
400
nm
0
200
400

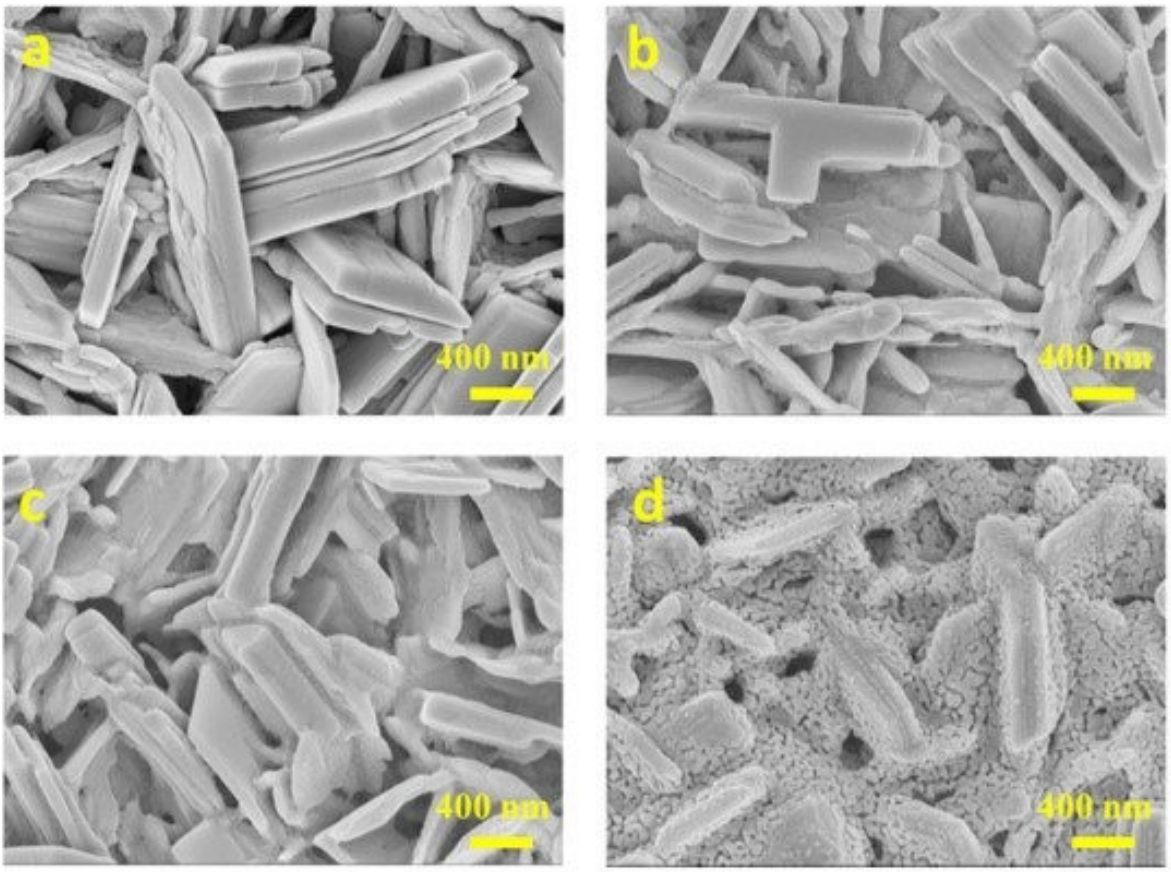

a
TaOx (3.5)
fcc-Ta (1.5)
fcc-Ru (3)
CoFeSiB (1.5)
fcc-Pt (2)
fcc-Pd (12.6)
fcc-Cu (2.1)
Si(111)
Co
Pd
Ru
2.25 nm
b
fcc(111)-Pd
0.225 nm
2D FFT
(1$\bar{1}$0)
(0$\bar{1}$1)
51°
62°
(10$\bar{1}$)
[111]
c
15 nm
d
Intensity (counts)
Sputter Time (s)
Ta
Ru
Co
B
Pt
Pd
Cu
e
Pd
f
Pt
g
Co
h
TaOx
Ta
CoFeSiB
Pt
Pd
1 nm

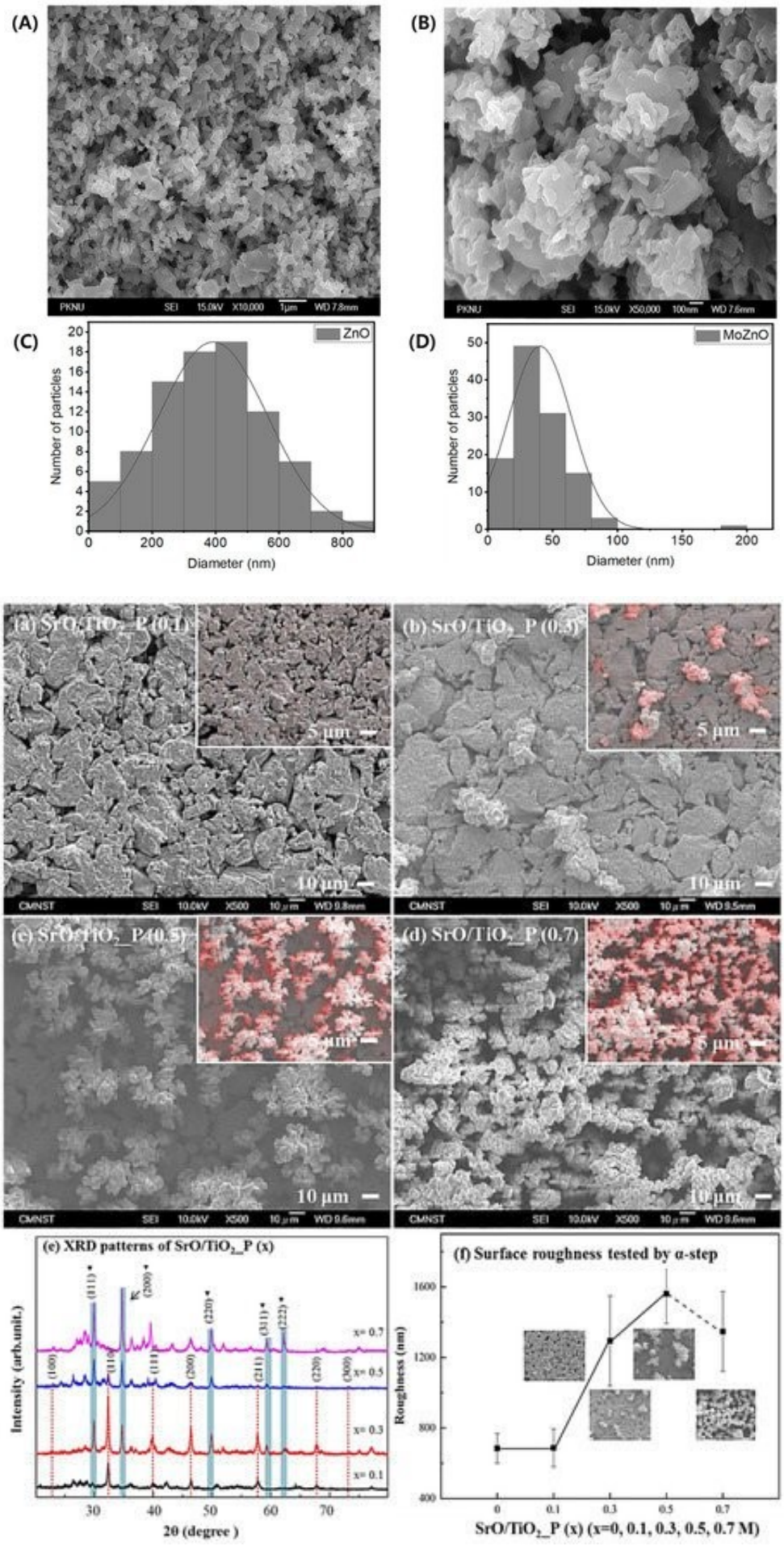

(a)
(b)
(c)
(d)
1
(e)
2
(f)
0.317 nm
CdS (200)
0.210 nm
NiO (101)
1
(g)
0.940 nm
1T-MoS2 (002)
0.210 nm
NiO (101)
2

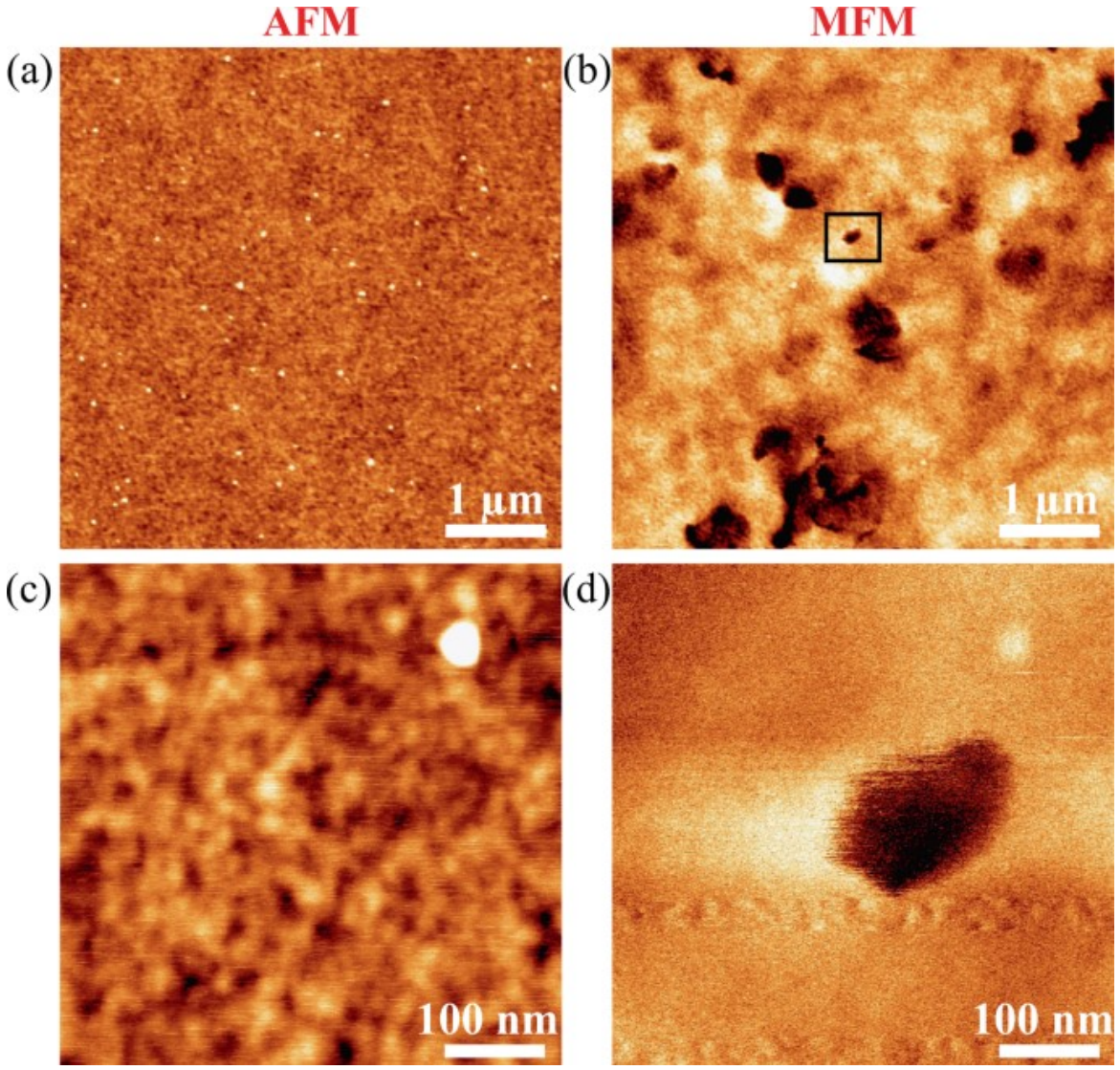

(a)
(b)
5mm
(c)

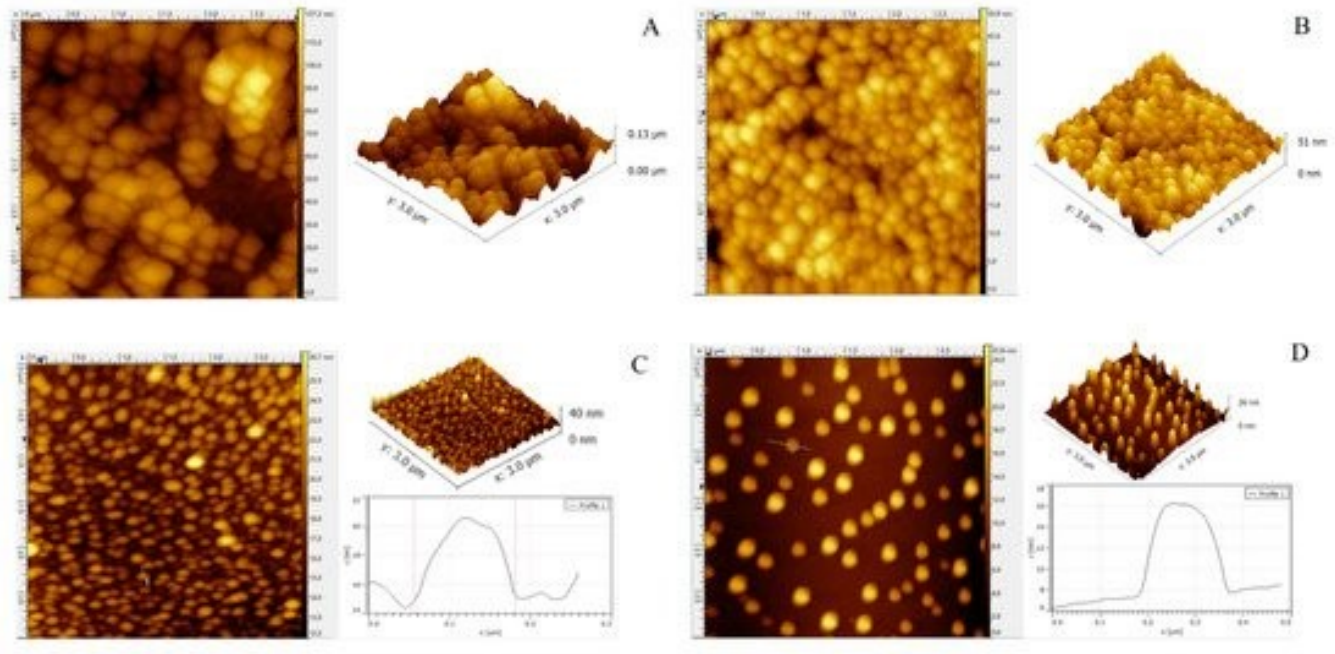

(a)
BF
(b)
HAADF
(c)
(d)
Cd
(e)
Mo
(f)
Ni
(g)
S

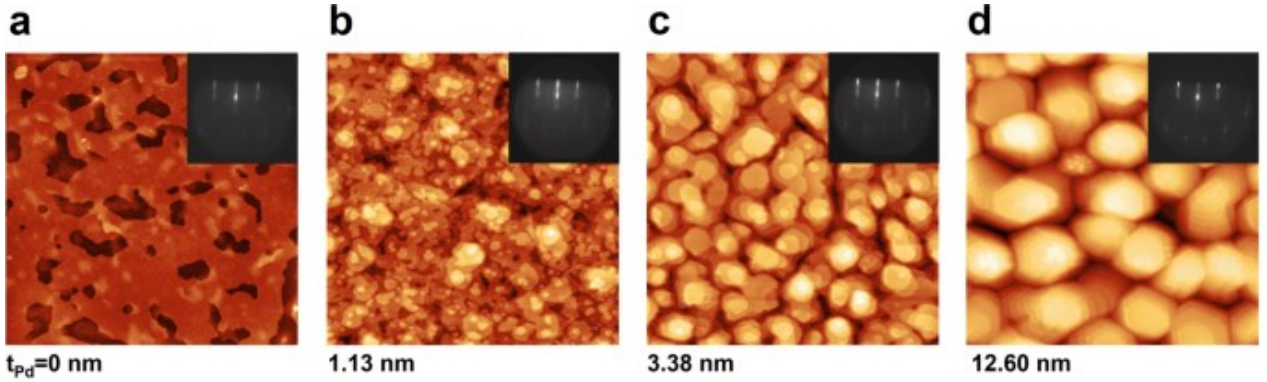

(a)
(b)
(c)
(d)
(e)
(f)
(g)
(h)
(i)

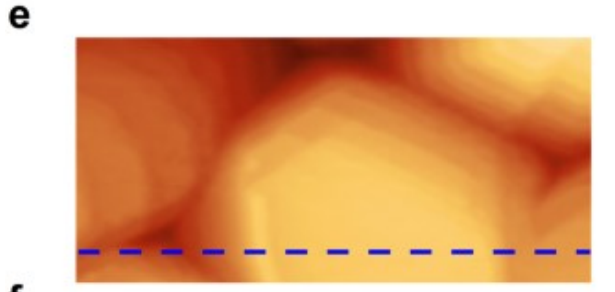

a
400 nm
b
400 nm
c
400 nm
d
400 nm

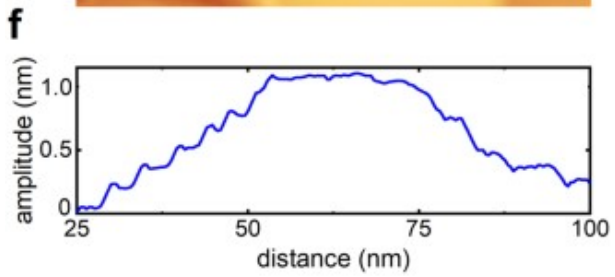

(A)
(B)
(C)
(D)
ZnO
MoZnO
Number of particles
Diameter (nm)
(a) SrO/TiO2_P(0.1)
(b) SrO/TiO2_P (0.3)
(c) SrO/TiO2_P(0.5)
(d) SrO/TiO2_P (0.7)
5 μm
10 μm
(e) XRD patterns of SrO/TiO2_P (x)
Intensity (arb.unit.)
2θ (degree)
x= 0.7
x= 0.5
x= 0.3
x= 0.1
(f) Surface roughness tested by α-step
Roughness (nm)
SrO/TiO2_P (x) (x=0, 0.1, 0.3, 0.5, 0.7 M)

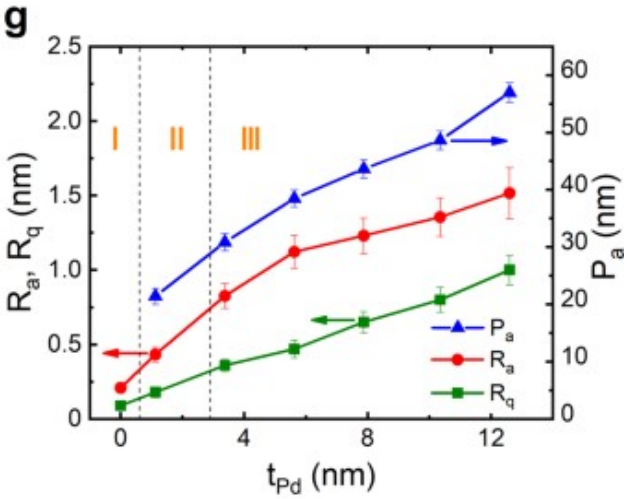

AFM
MFM
(a)
(b)
1 µm
1 µm
(c)
(d)
100 nm
100 nm

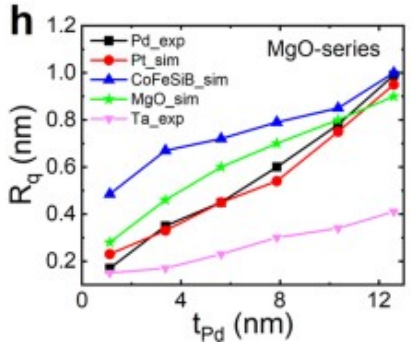

A
B
C
D

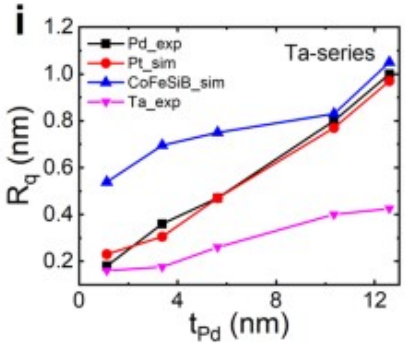

a
b
c
d
t_{Pd}=0 nm
1.13 nm
3.38 nm
12.60 nm

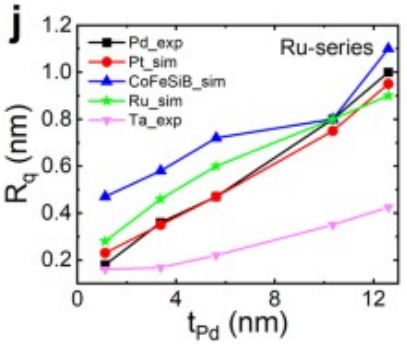

e

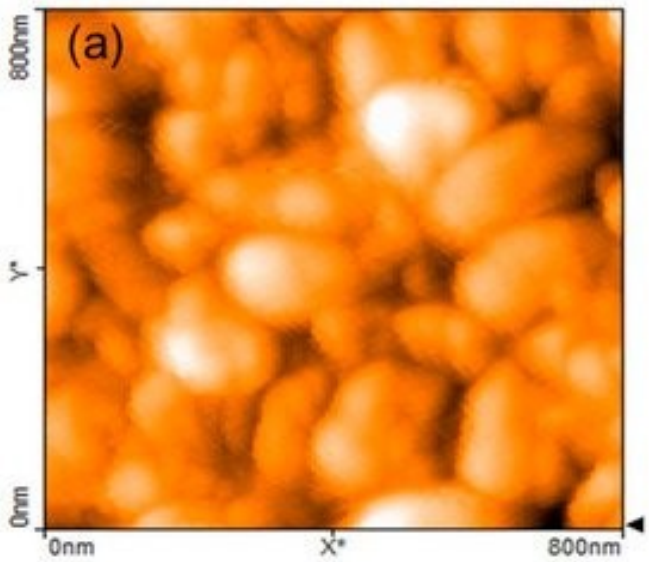

f
amplitude (nm)
distance (nm)

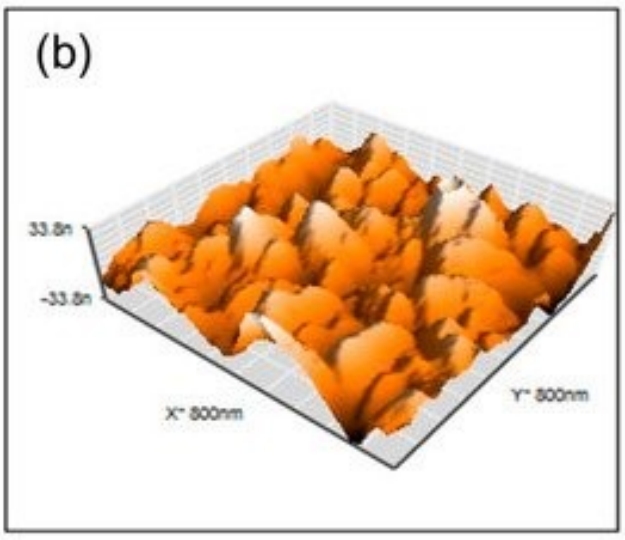

g
R_a, R_q (nm)
P_a (nm)
t_{Pd} (nm)
I
II
III
P_a
R_a
R_q

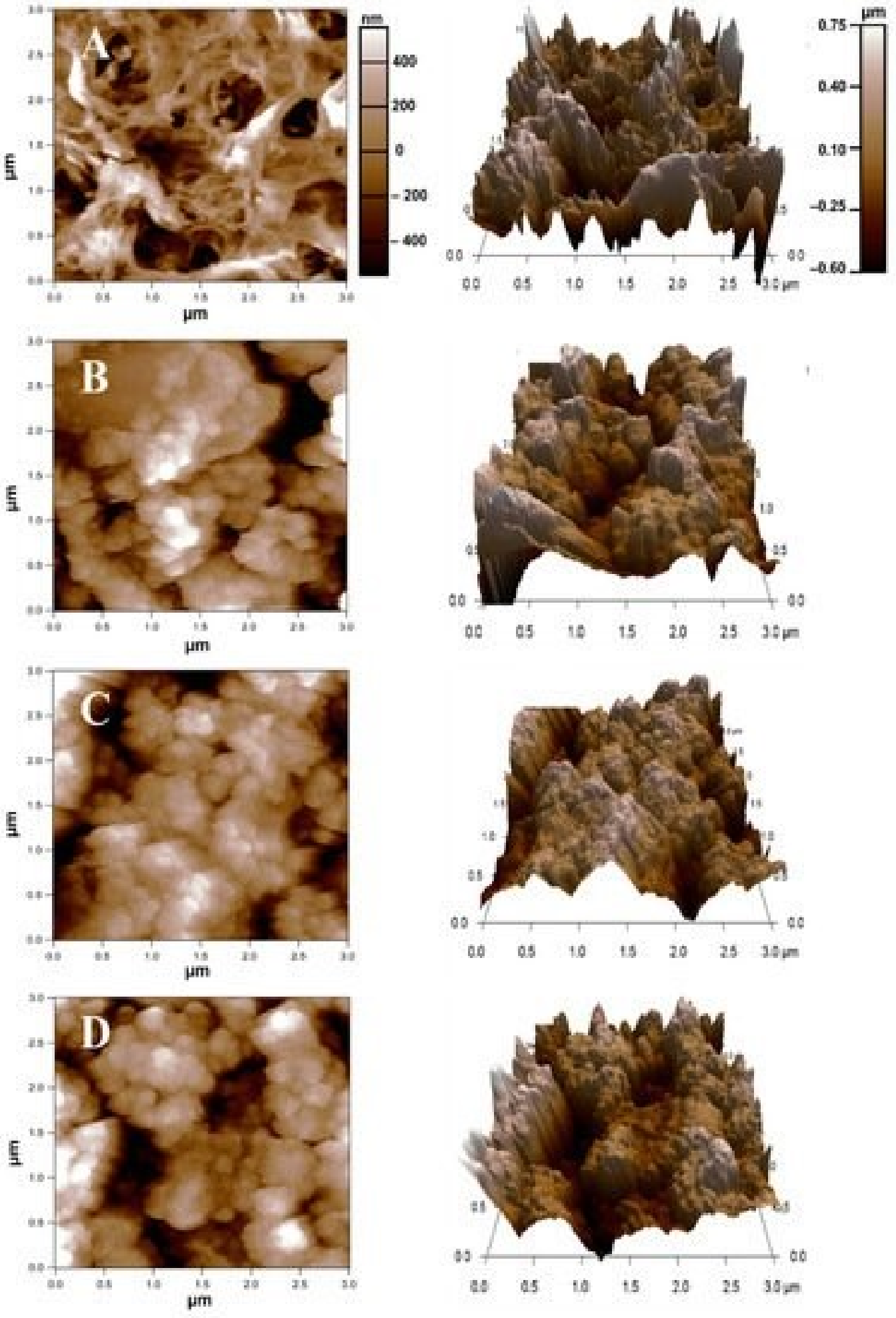

h
MgO-series
Pd_exp
Pt_sim
CoFeSiB_sim
MgO_sim
Ta_exp
R_q (nm)
t_{Pd} (nm)

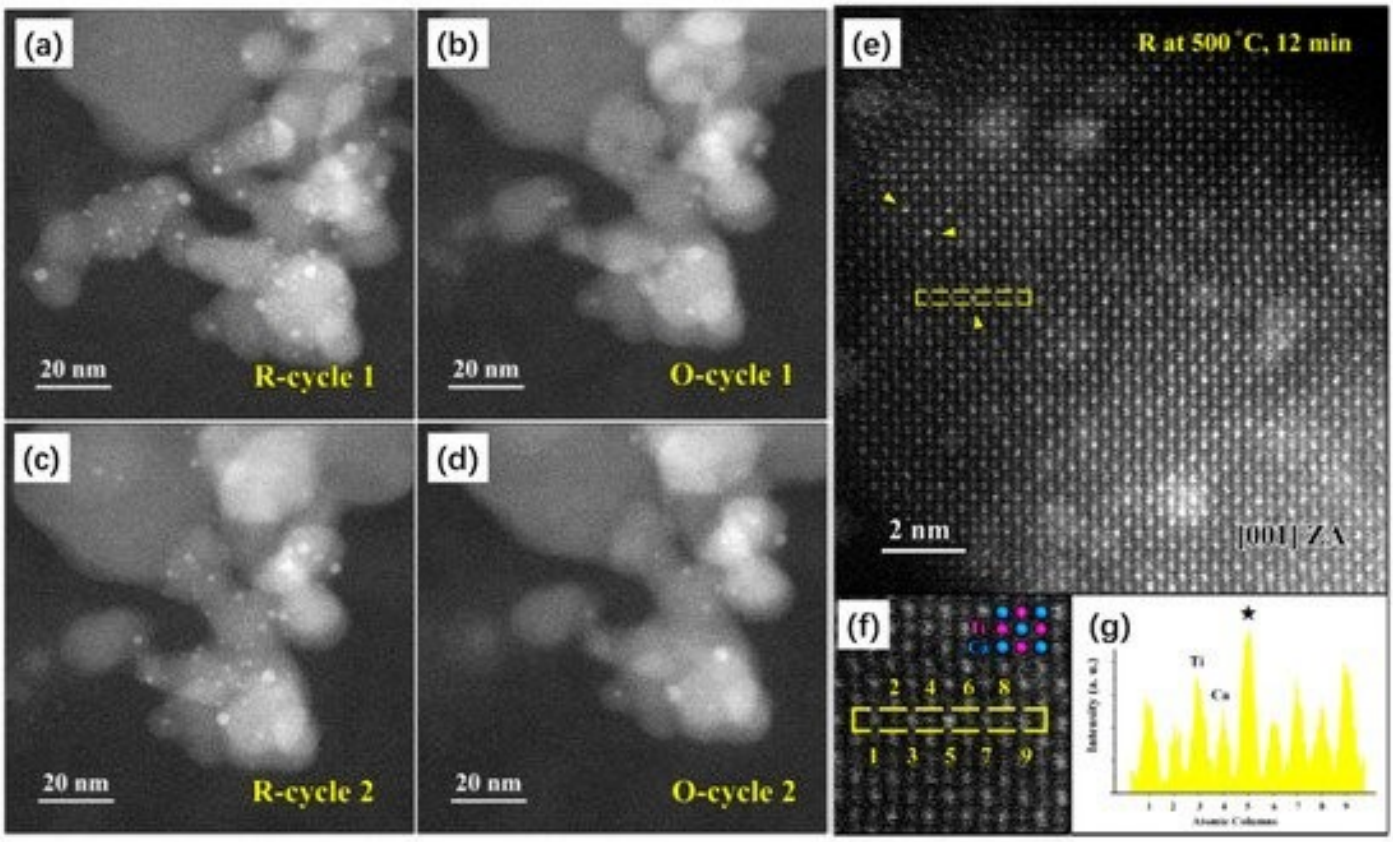

i
Ta-series
Pd_exp
Pt_sim
CoFeSiB_sim
Ta_exp
R_q (nm)
t_{Pd} (nm)

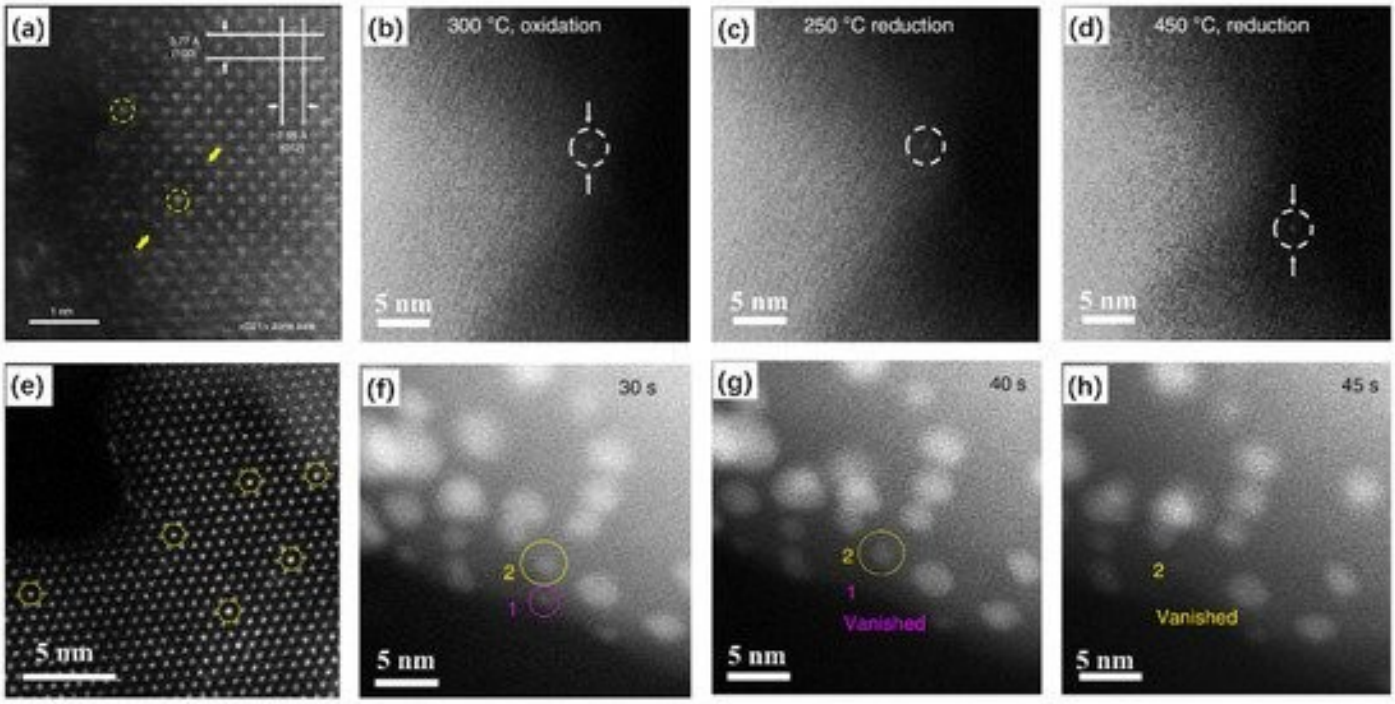

j
Ru-series
Pd_exp
Pt_sim
CoFeSiB_sim
Ru_sim
Ta_exp
R_q (nm)
t_{Pd} (nm)

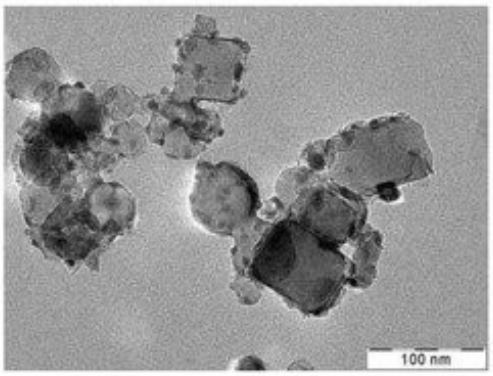

(a)
800nm
Y*
0nm
0nm
X*
800nm


(b)
33.8n
-33.8n
X* 800nm
Y* 800nm

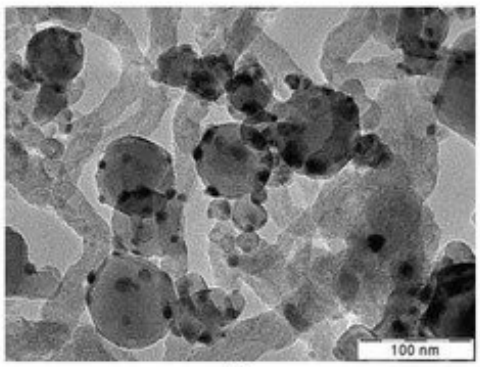

A
B
C
D
nm
400
200
0
– 200
– 400
µm
0.75
0.40
0.10
–0.25
–0.60
0.0
0.5
1.0
1.5
2.0
2.5
3.0 µm


(a)
20 nm
R-cycle 1
(b)
20 nm
O-cycle 1
(c)
20 nm
R-cycle 2
(d)
20 nm
O-cycle 2
(e)
R at 500 °C, 12 min
2 nm
[001] ZA
(f)
Ti
Ca
2 4 6 8
1 3 5 7 9
(g)
Ti
Ca
Intensity (A. u.)
Atomic Columns

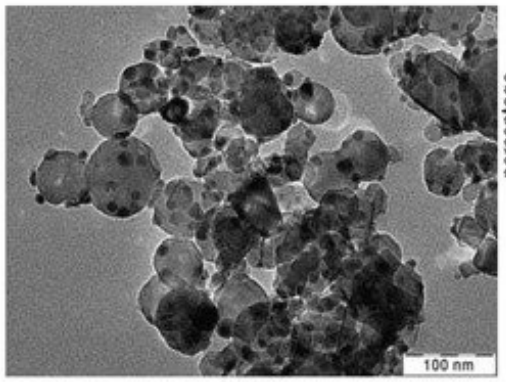

(a)
(b)
300 °C, oxidation
5 nm
(c)
250 °C reduction
5 nm
(d)
450 °C, reduction
5 nm
(e)
5 nm
(f)
30 s
2
1
5 nm
(g)
40 s
2
1
Vanished
5 nm
(h)
45 s
2
Vanished
5 nm


100 nm

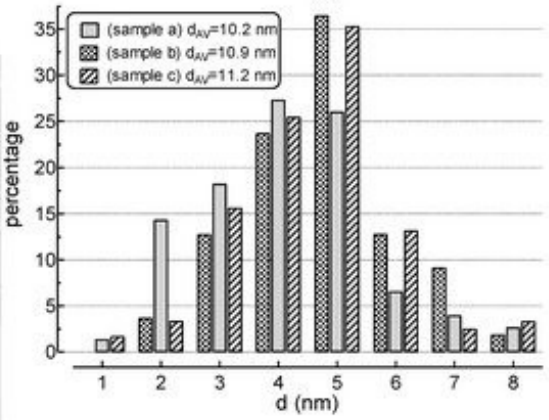
(A)


100 nm

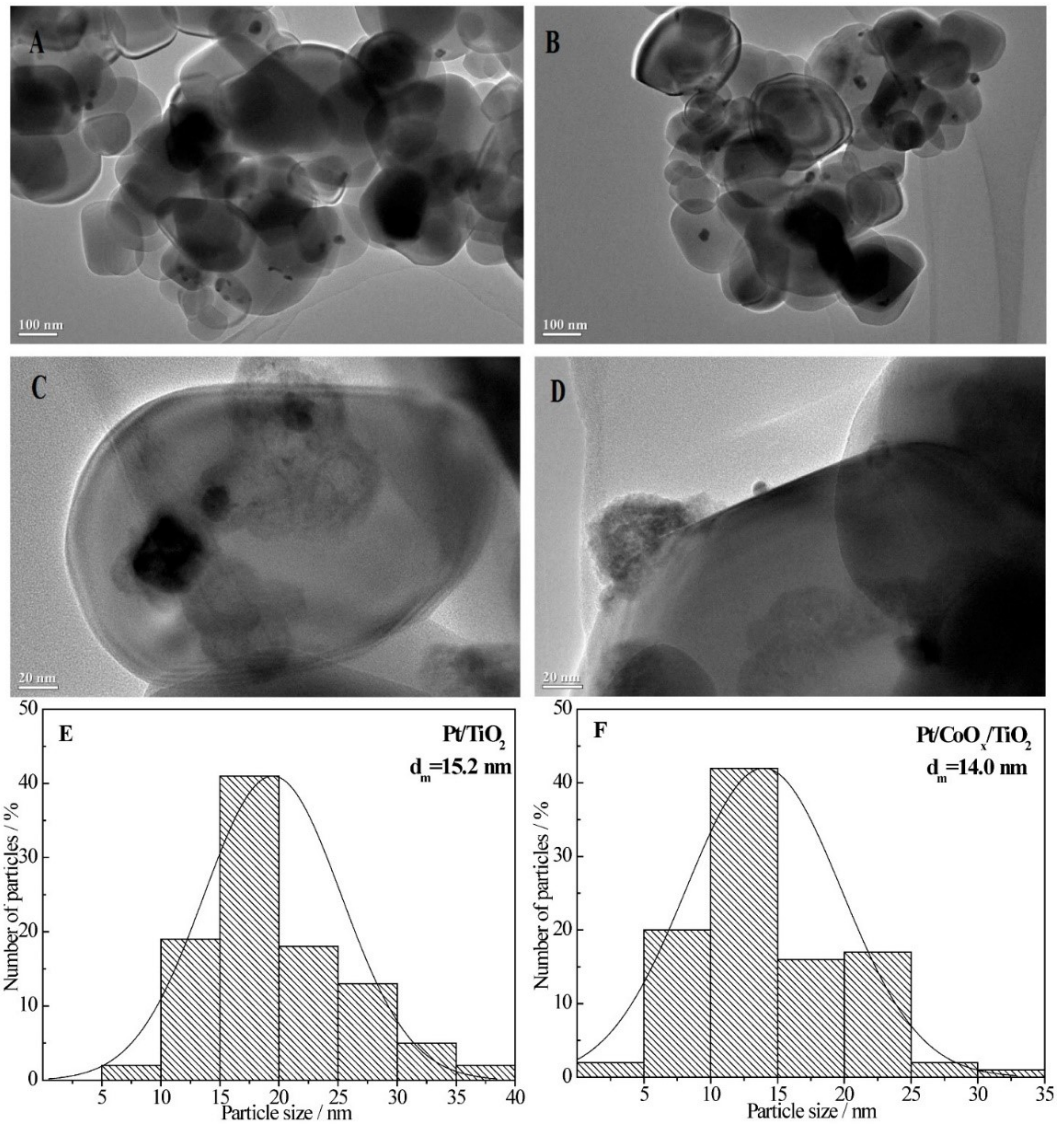
(B)

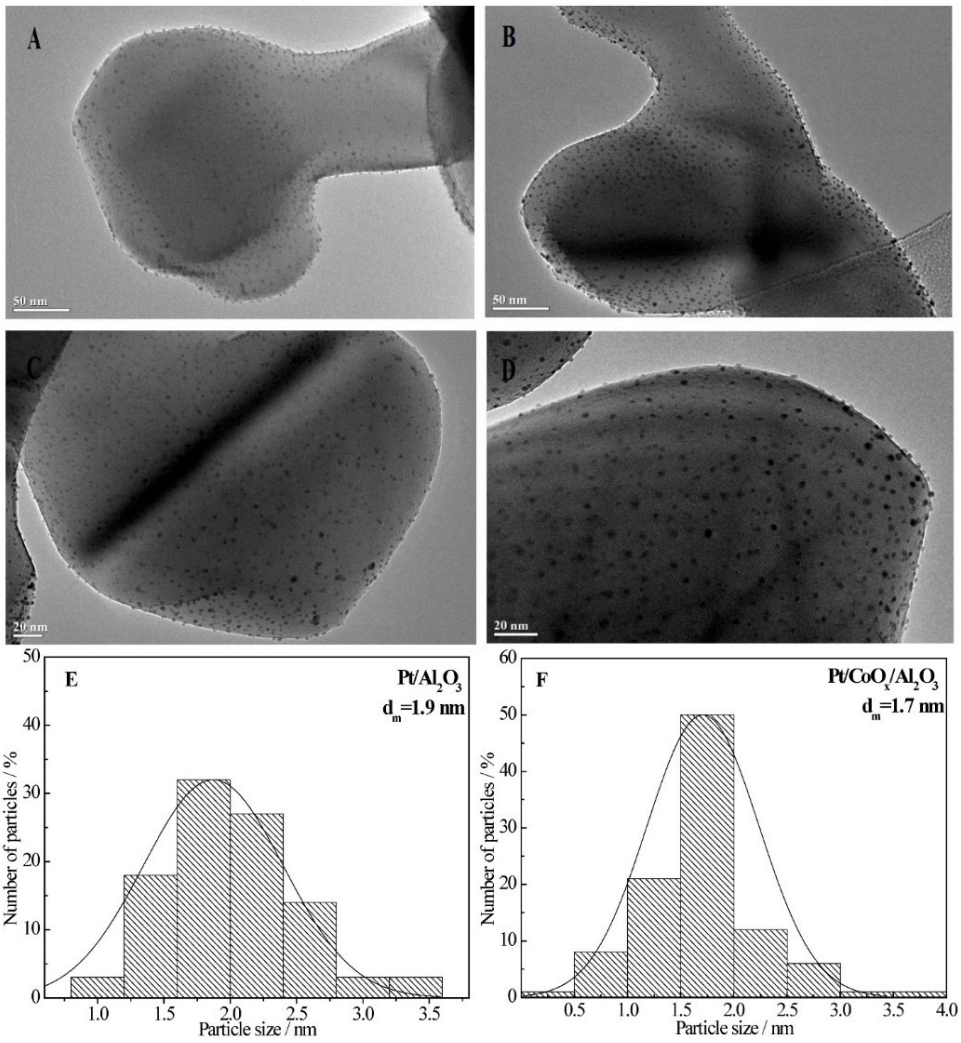

100 nm

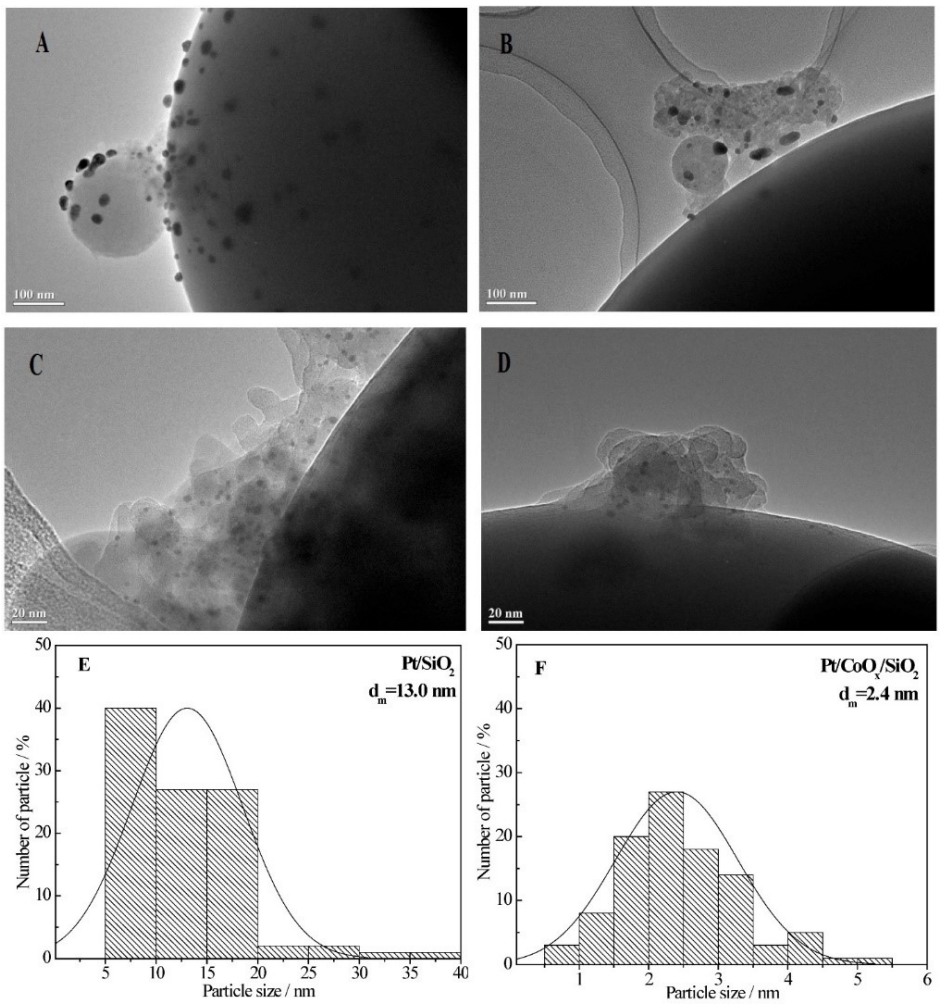
(C)

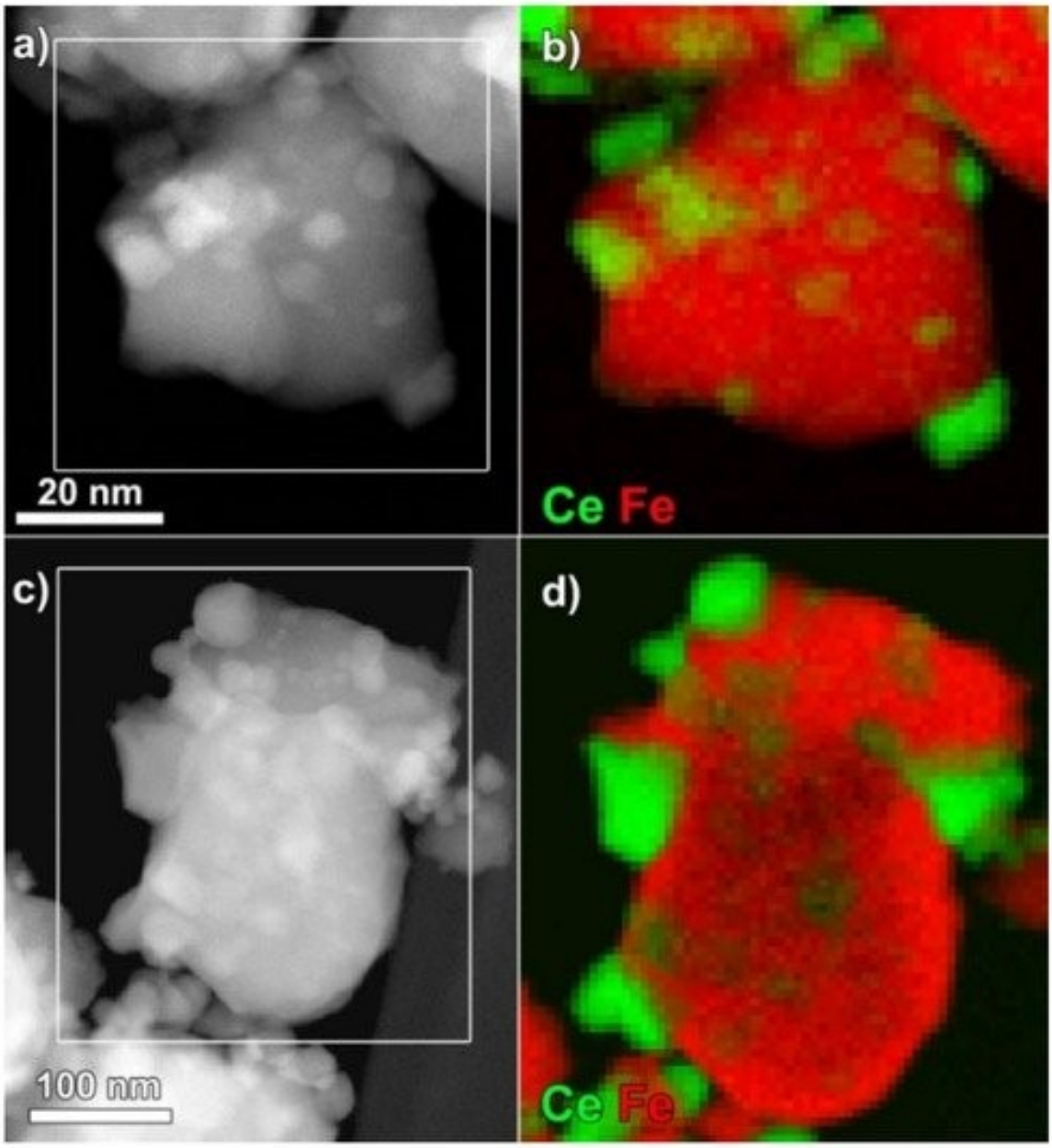

(sample a) d_{AV}=10.2 nm
(sample b) d_{AV}=10.9 nm
(sample c) d_{AV}=11.2 nm
percentage
d (nm)

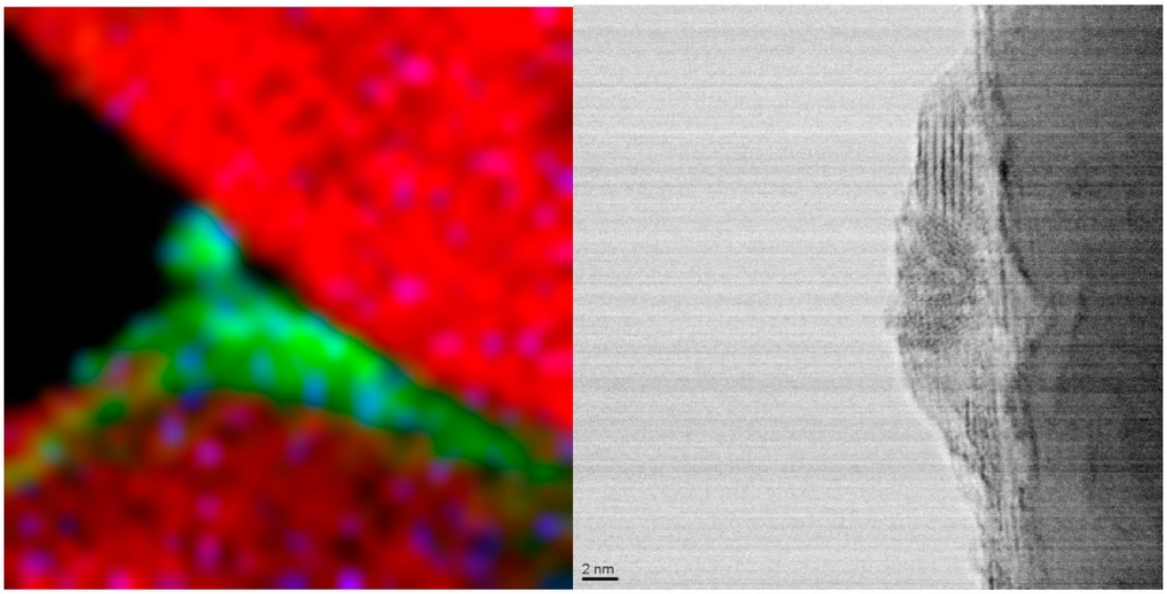
(D)

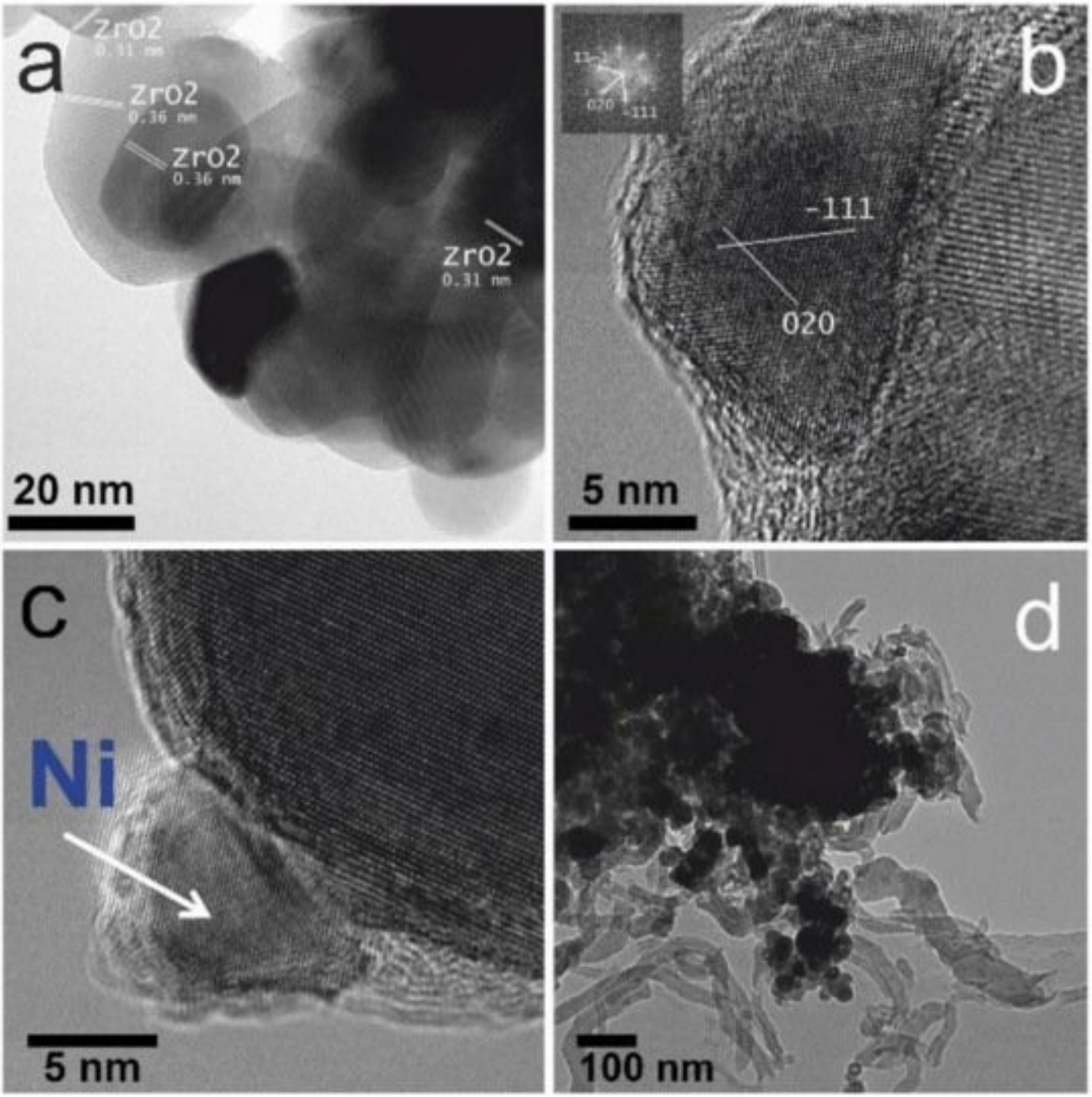

A
100 nm
B
100 nm
C
20 nm
D
20 nm
E
Pt/TiO2
dm=15.2 nm
Number of particles / %
Particle size / nm
F
Pt/CoOx/TiO2
dm=14.0 nm
Number of particles / %
Particle size / nm

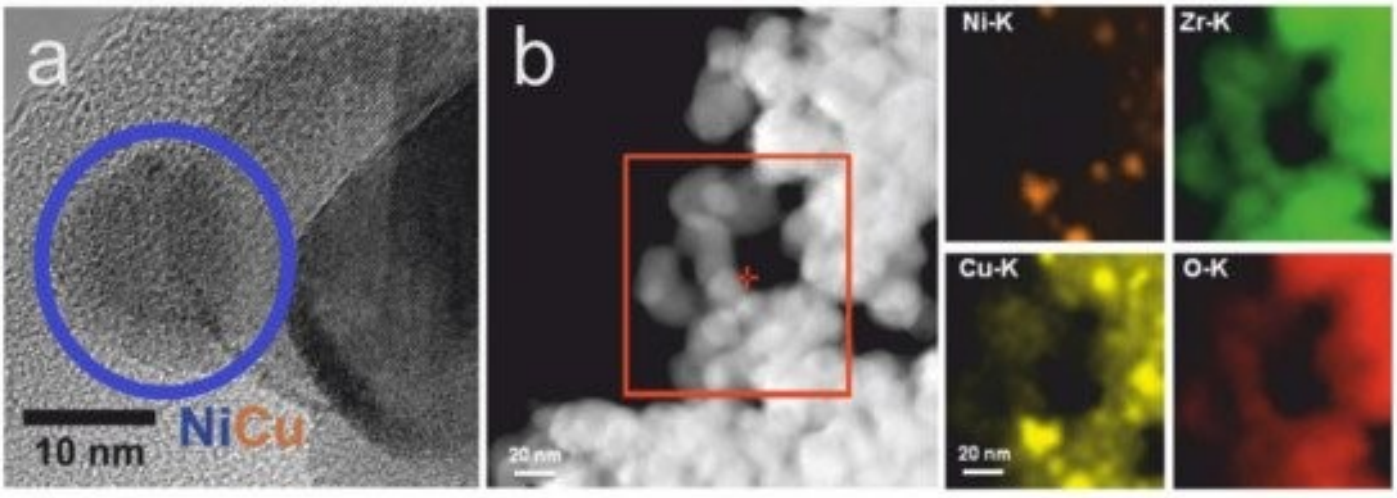

A
50 nm
B
50 nm
C
20 nm
D
20 nm
E
Pt/Al2O3
dm=1.9 nm
Number of particles / %
Particle size / nm
F
Pt/CoOx/Al2O3
dm=1.7 nm
Number of particles / %
Particle size / nm

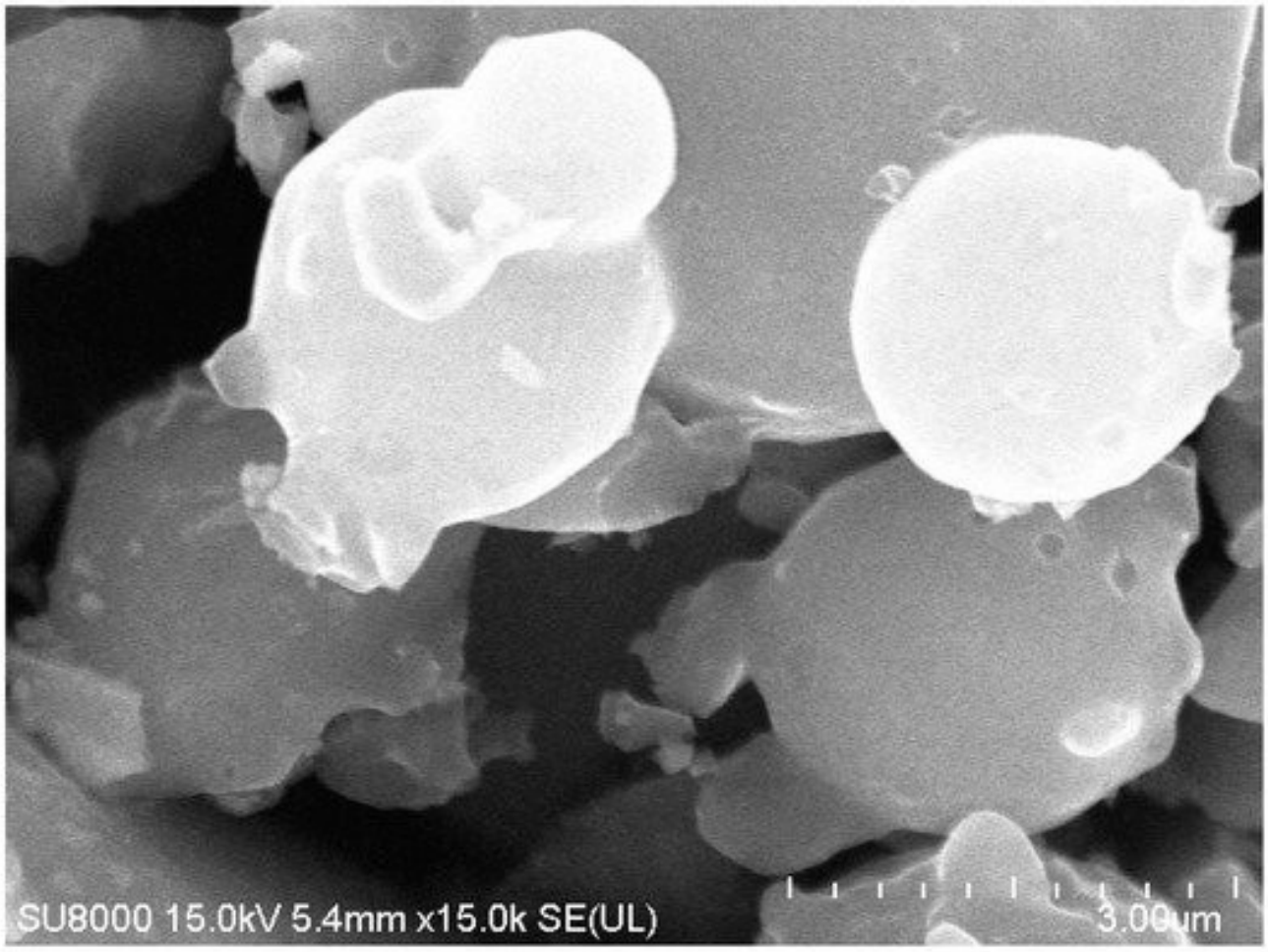

A
100 nm
B
100 nm
C
20 nm
D
20 nm
E
Pt/SiO2
dm=13.0 nm
Number of particle / %
Particle size / nm
F
Pt/CoOx/SiO2
dm=2.4 nm
Number of particle / %
Particle size / nm

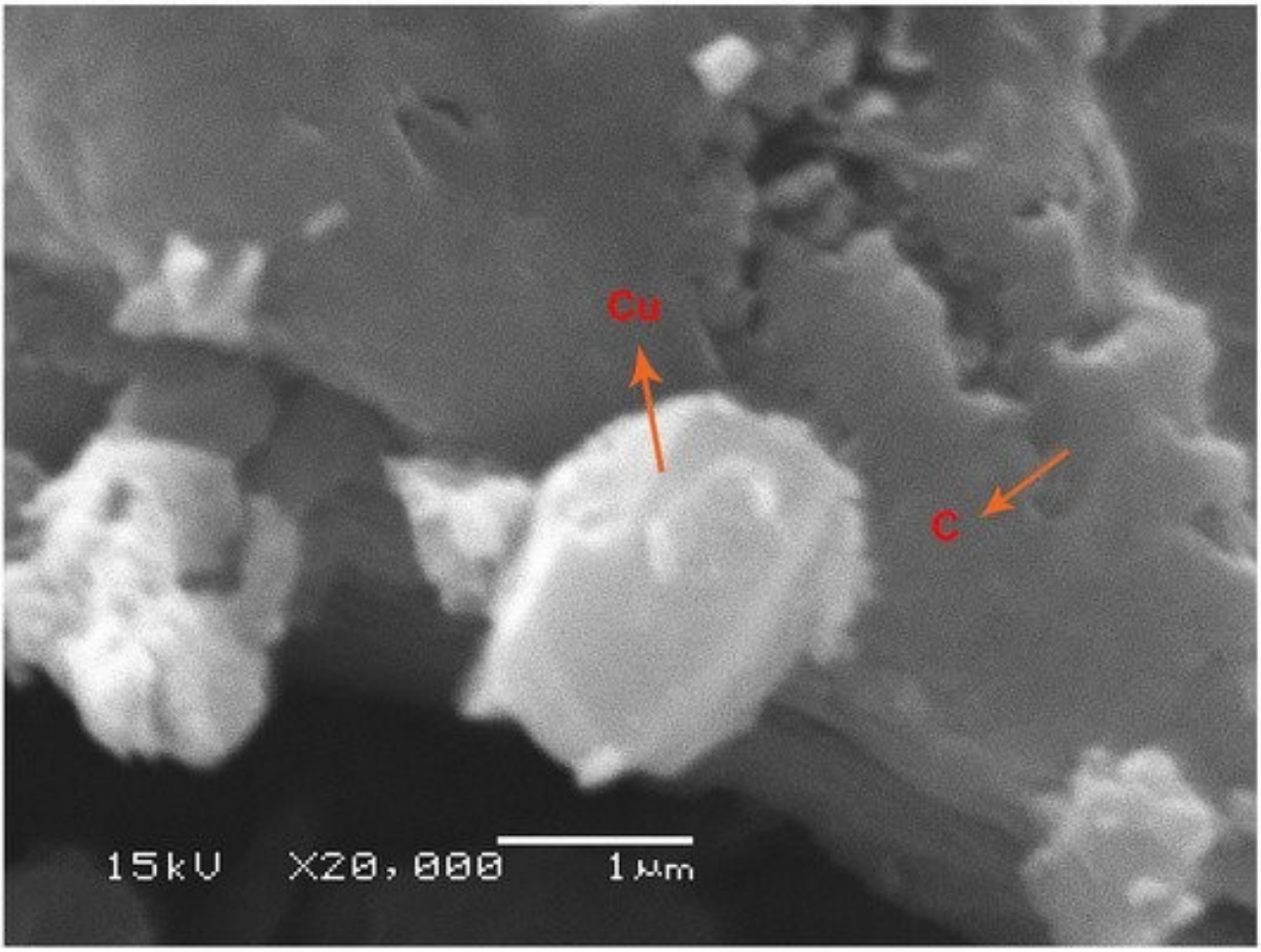

a)
20 nm
b)
Ce Fe
c)
100 nm
d)
Ce Fe

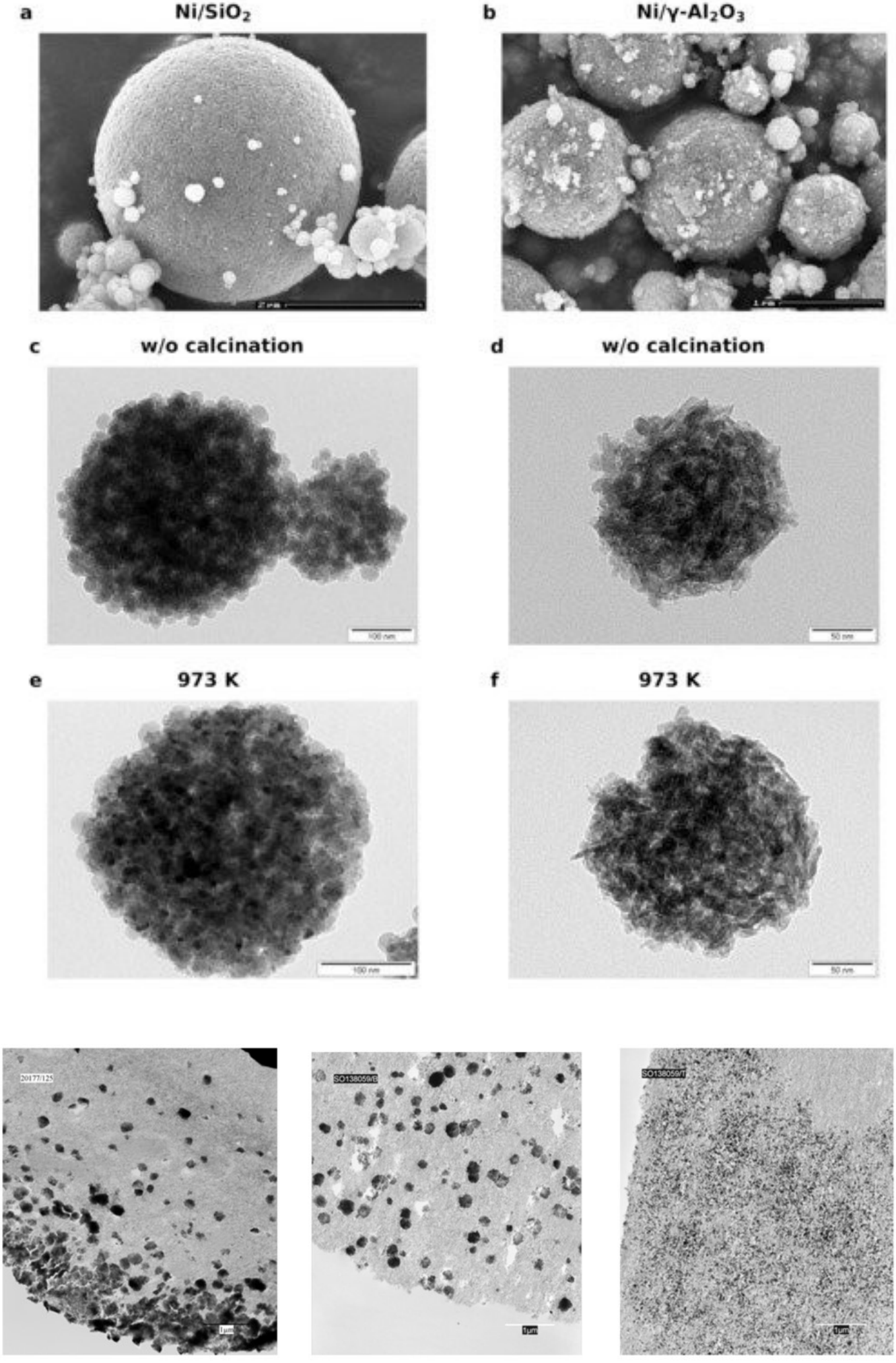

2 nm

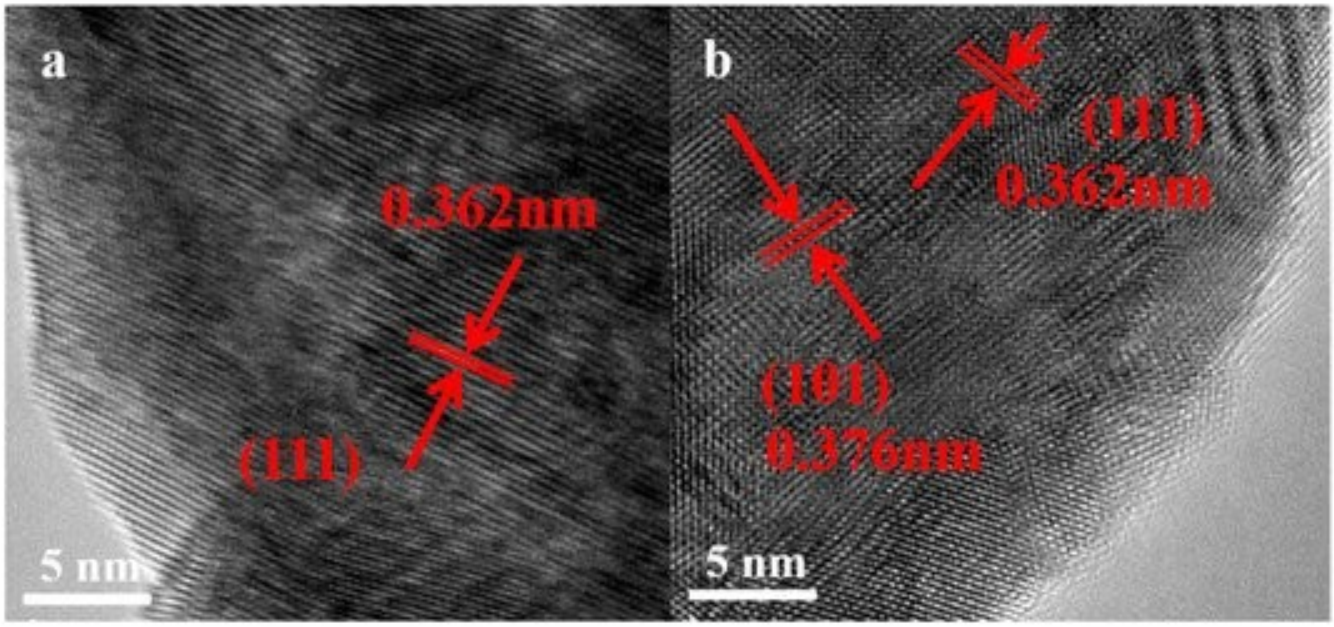

a
ZrO2
0.31 nm
ZrO2
0.36 nm
ZrO2
0.36 nm
ZrO2
0.31 nm
20 nm
b
-111
020
5 nm
c
Ni
5 nm
d
100 nm

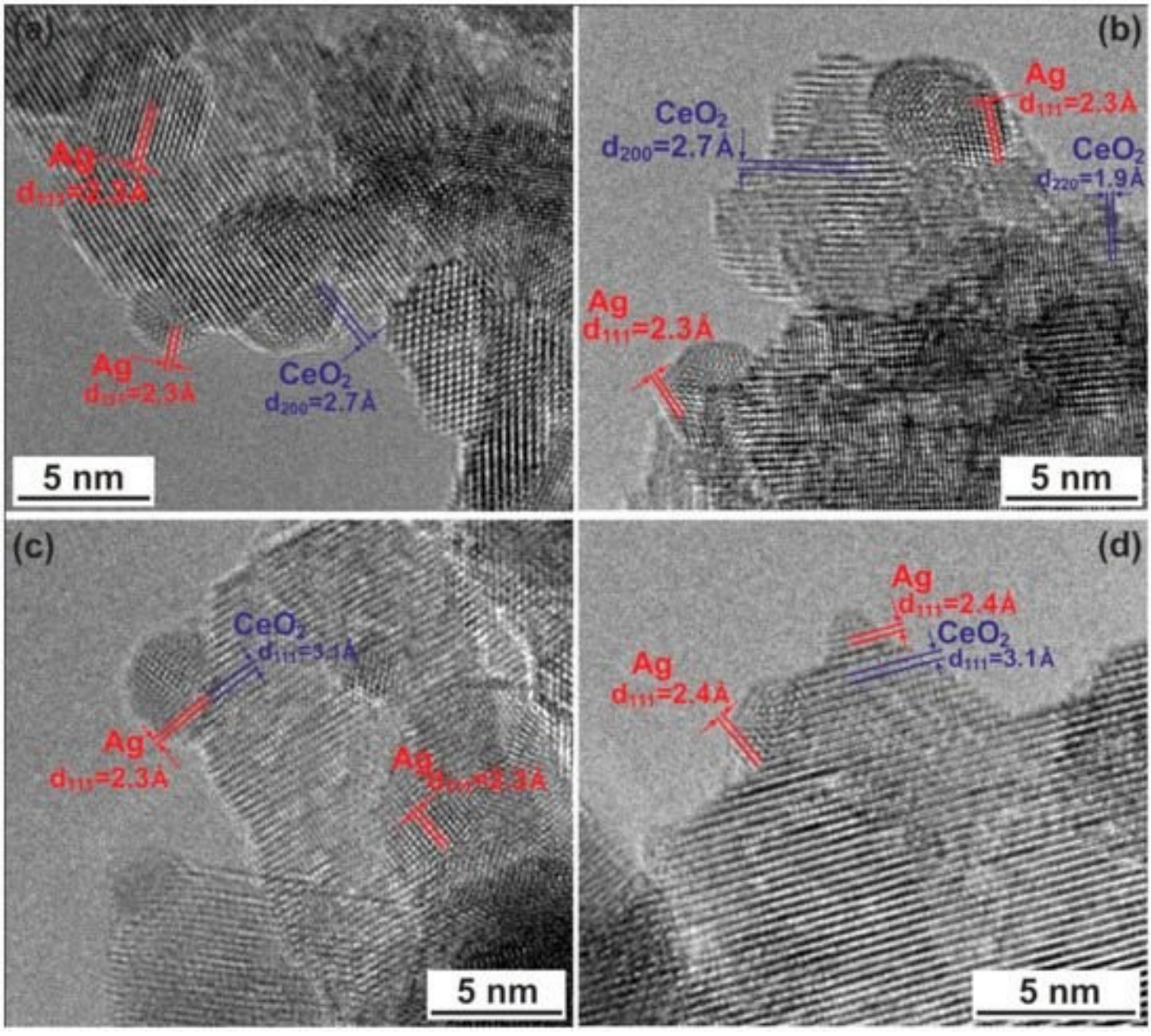

a
10 nm
NiCu
b
20 nm
Ni-K
Zr-K
Cu-K
20 nm
O-K

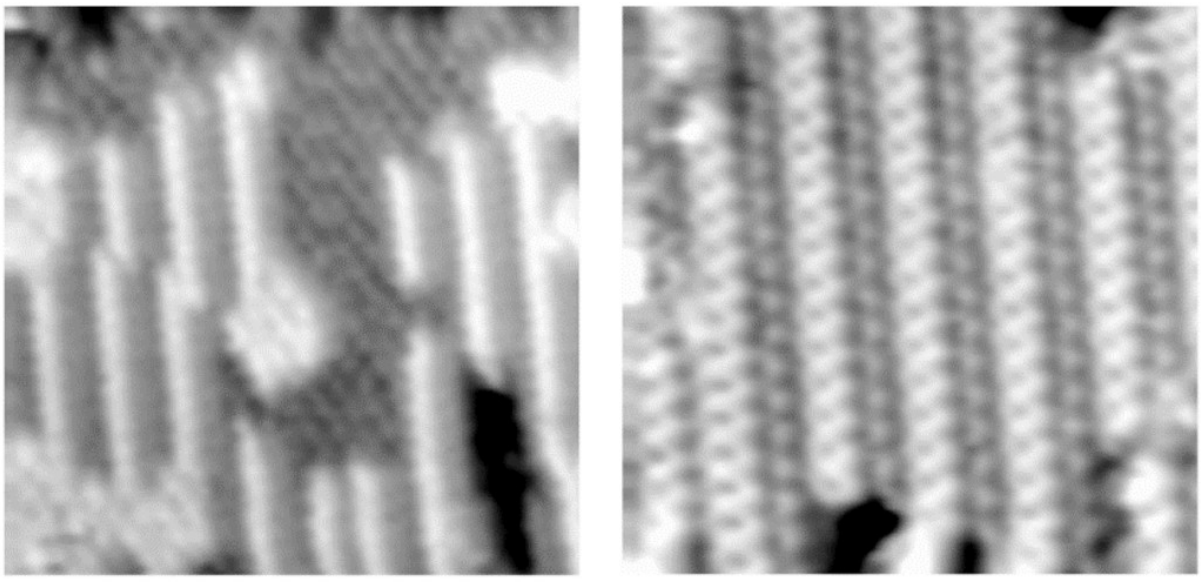

SU8000 15.0kV 5.4mm x15.0k SE(UL)
3.00um


Cu
C
15kV X20,000 1μm

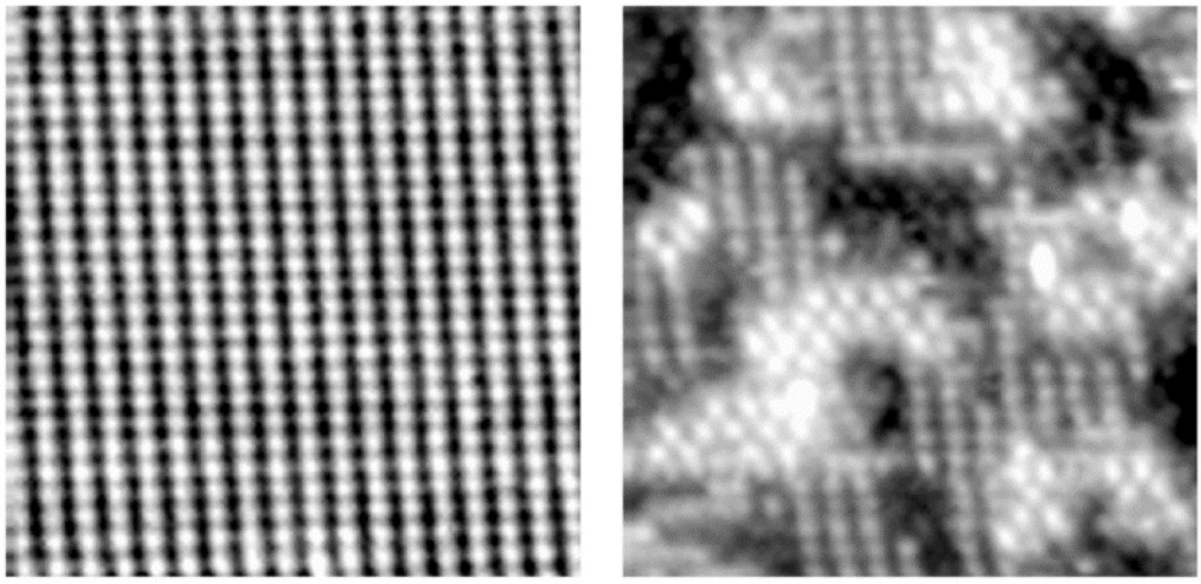

a
Ni/SiO2
b
Ni/γ-Al2O3
c
w/o calcination
d
w/o calcination
e
973 K
f
973 K


a
0.362nm
(111)
5 nm
b
(111)
0.362nm
(101)
0.376nm
5 nm

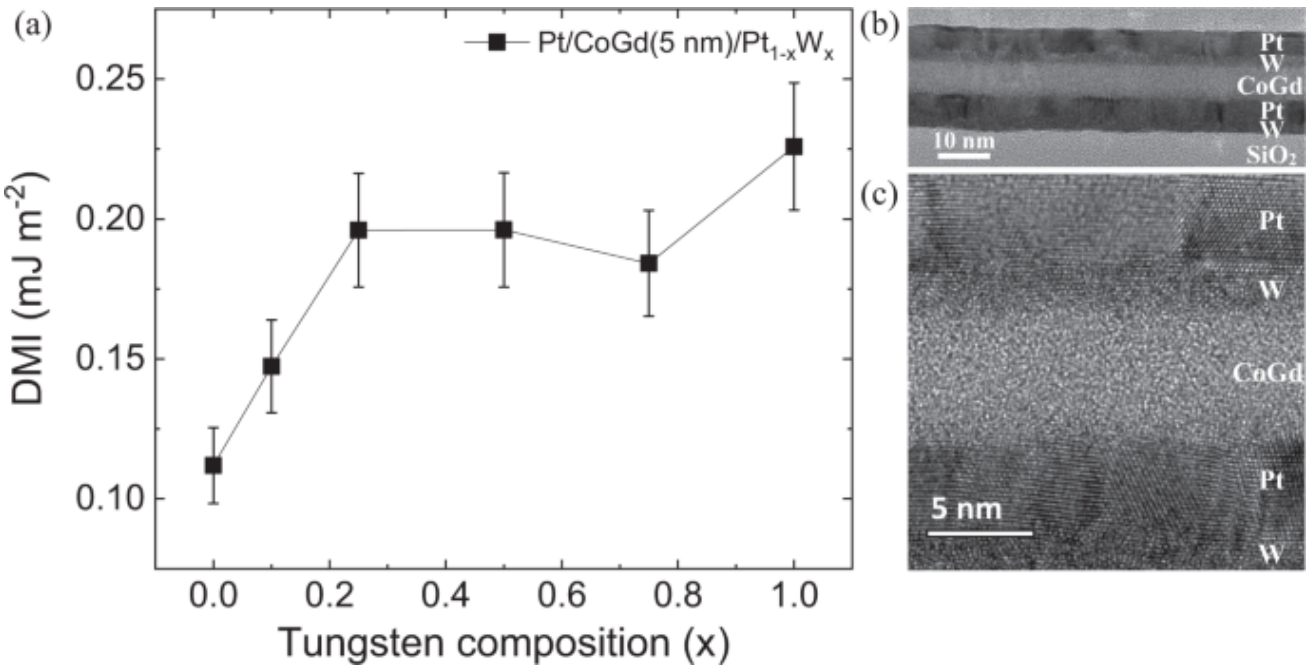

(a)
Ag
d111=2.3Å
Ag
d111=2.3Å
CeO2
d200=2.7Å
5 nm
(b)
Ag
d111=2.3Å
CeO2
d200=2.7Å
CeO2
d220=1.9Å
Ag
d111=2.3Å
5 nm
(c)
CeO2
d111=3.1Å
Ag
d111=2.3Å
Ag
d111=2.3Å
5 nm
(d)
Ag
d111=2.4Å
CeO2
d111=3.1Å
Ag
d111=2.4Å
5 nm

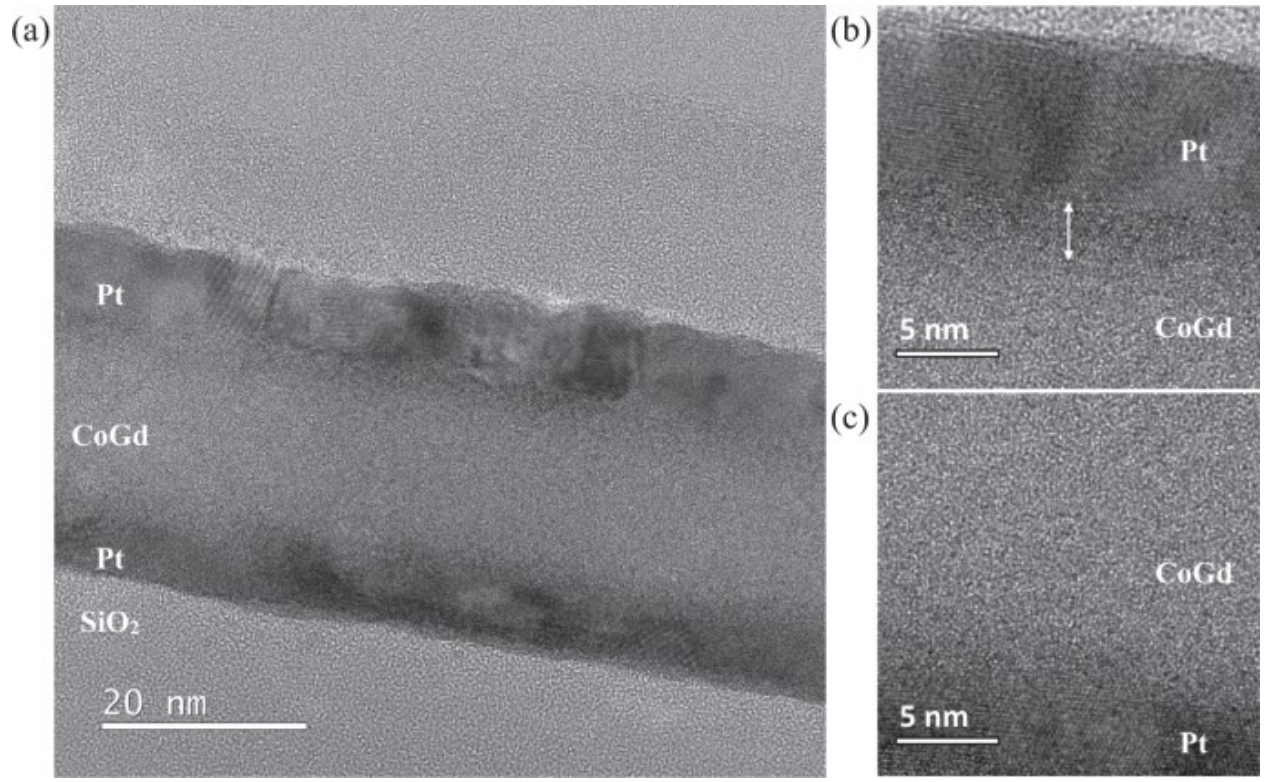


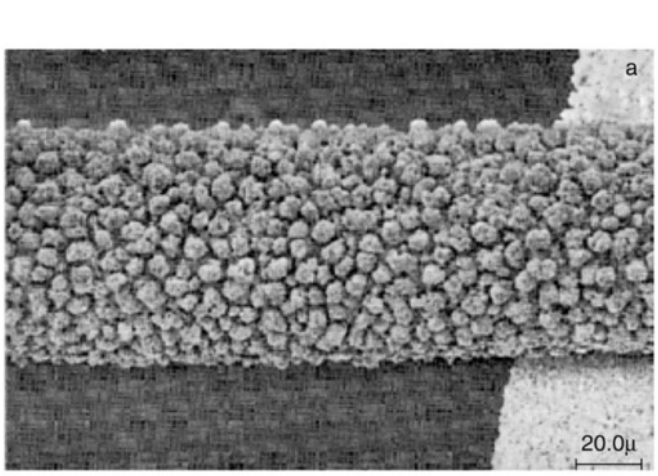
(c) (d)



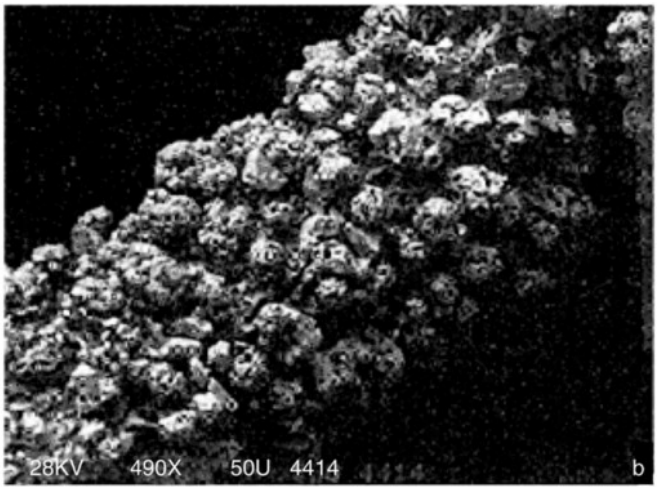
(a) (b)


(a)
Pt/CoGd(5 nm)/Pt1-xWx
DMI (mJ m-2)
0.25
0.20
0.15
0.10
0.0
0.2
0.4
0.6
0.8
1.0
Tungsten composition (x)
(b)
Pt
W
CoGd
Pt
W
10 nm
SiO2
(c)
Pt
W
CoGd
Pt
5 nm
W

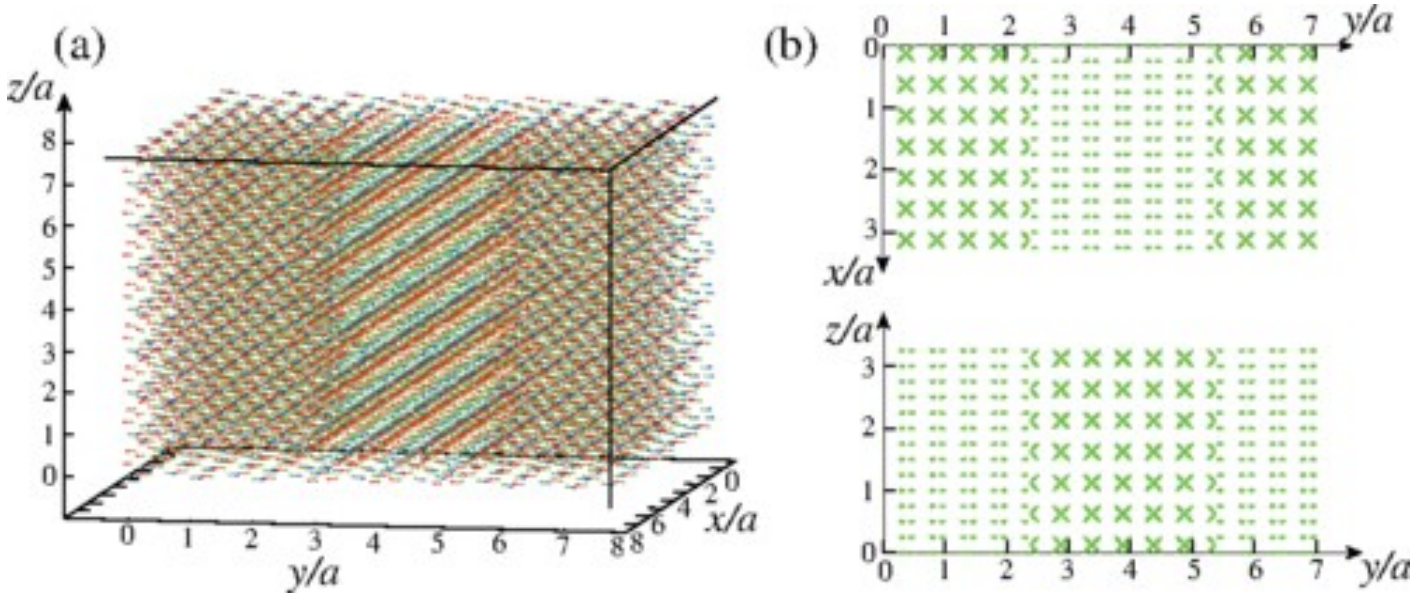

(a)
Pt
CoGd
Pt
SiO2
20 nm
(b)
Pt
5 nm
CoGd
(c)
CoGd
5 nm
Pt

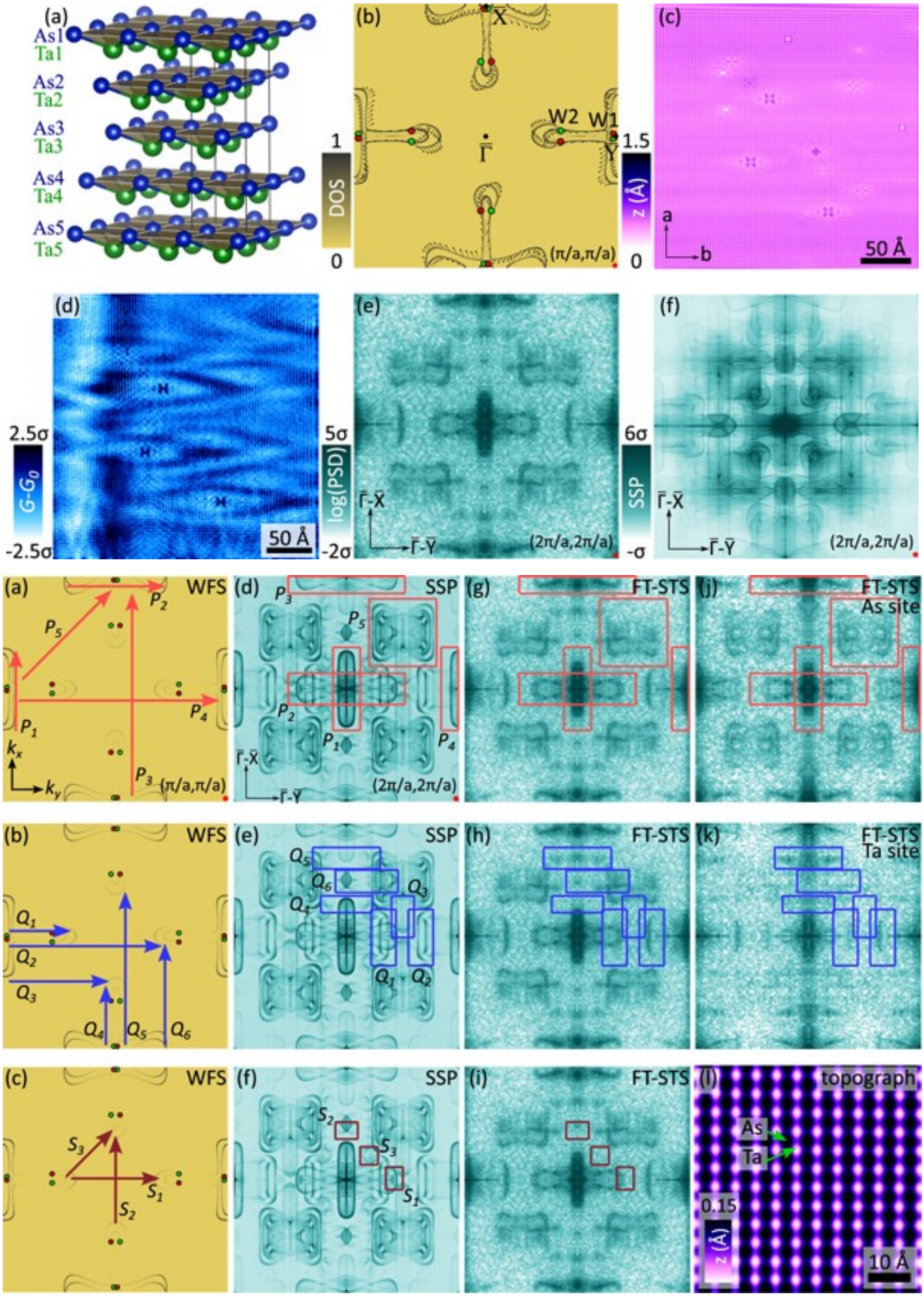

a
20.0µ

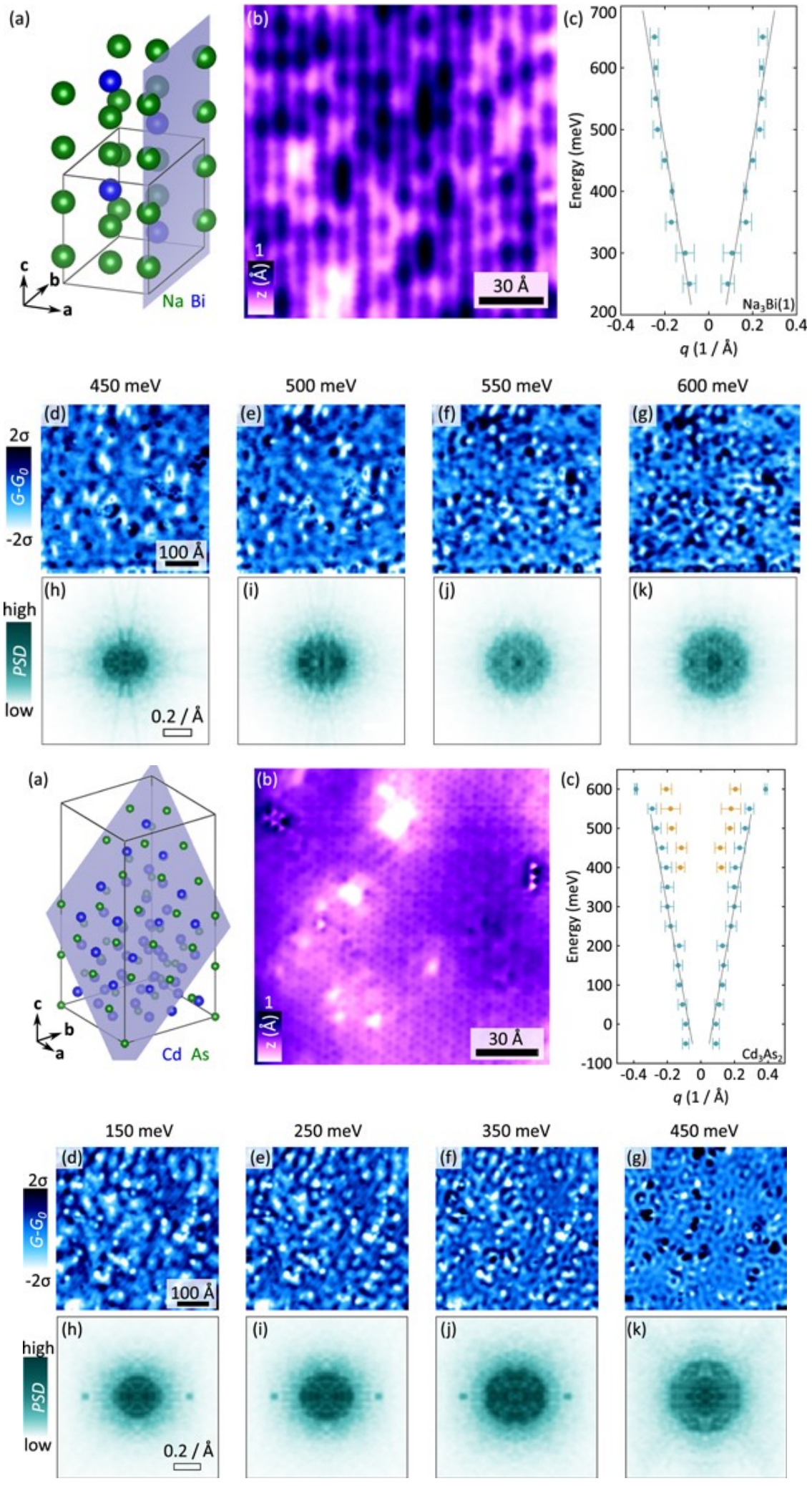
(**a**)

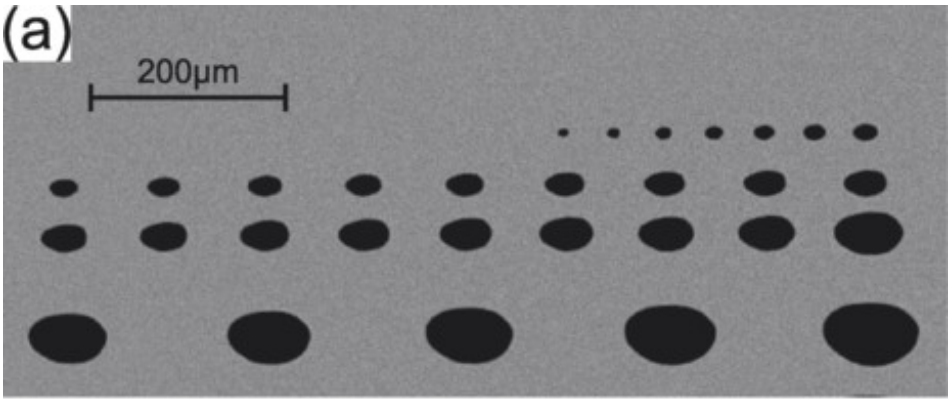

28KV 490X 50U 4414
b

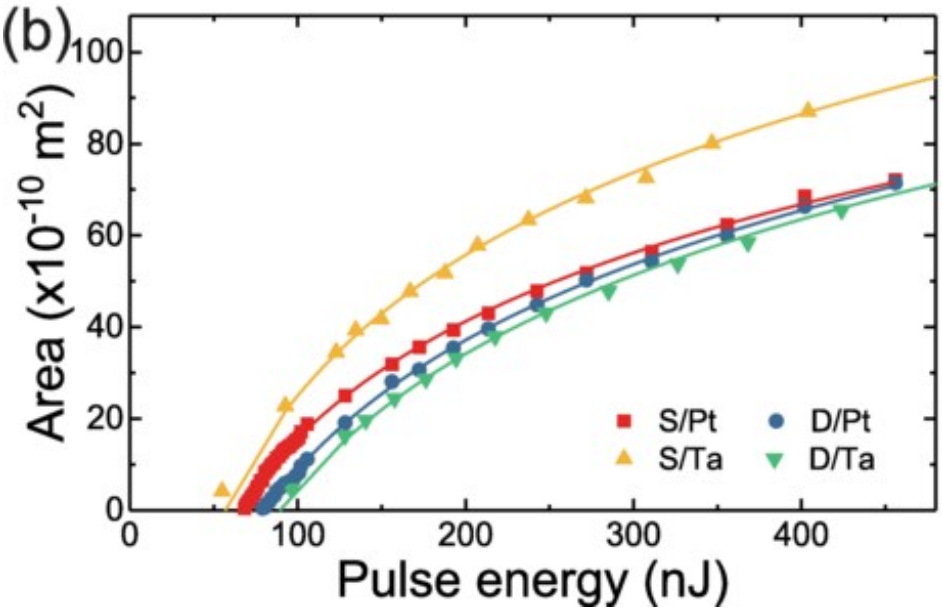
(**b**)

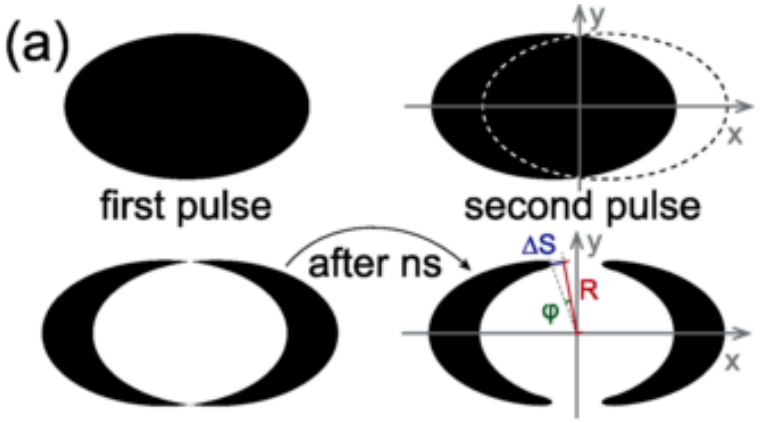

(a)
z/a
y/a
x/a
(b)
y/a
x/a
z/a
y/a

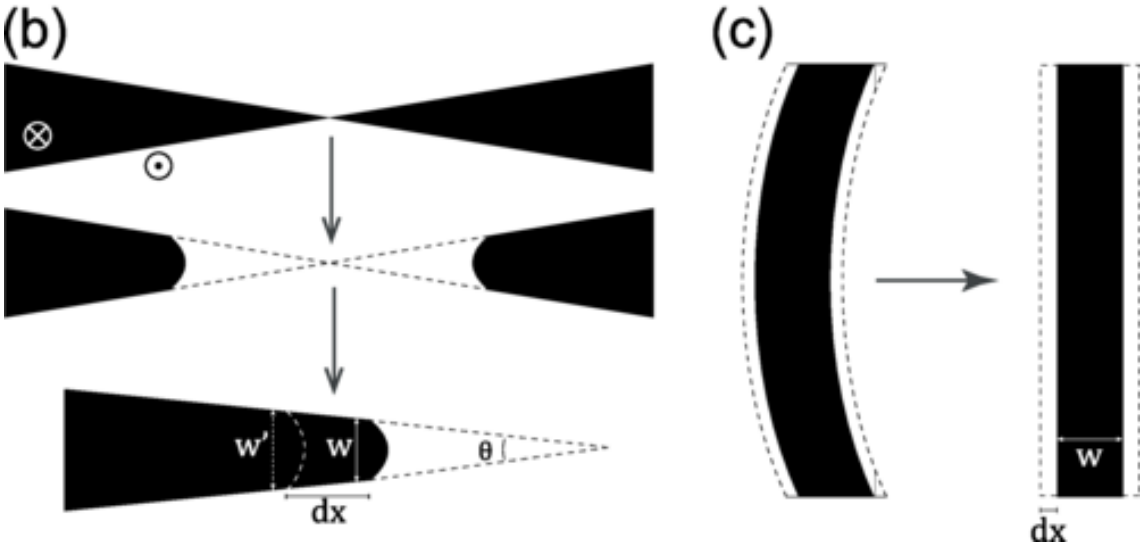

(a)
As1
Ta1
As2
Ta2
As3
Ta3
As4
Ta4
As5
Ta5
(b)
X̄
W2
W1
Γ̄
Ȳ
1
DOS
0
(π/a,π/a)
(c)
1.5
z (Å)
0
a
b
50 Å
(d)
2.5σ
G-G0
-2.5σ
50 Å
(e)
5σ
log(PSD)
-2σ
Γ̄-X̄
Γ̄-Ȳ
(2π/a,2π/a)
(f)
6σ
SSP
-σ
Γ̄-X̄
Γ̄-Ȳ
(2π/a,2π/a)
(a) WFS
P1
P2
P3
P4
P5
kx
ky
(π/a,π/a)
(d) SSP
(2π/a,2π/a)
(g) FT-STS
(j) FT-STS
As site
(b) WFS
Q1
Q2
Q3
Q4
Q5
Q6
(e) SSP
(h) FT-STS
(k) FT-STS
Ta site
(c) WFS
S1
S2
S3
(f) SSP
(i) FT-STS
(l) topograph
As
Ta
0.15
z (Å)
10 Å

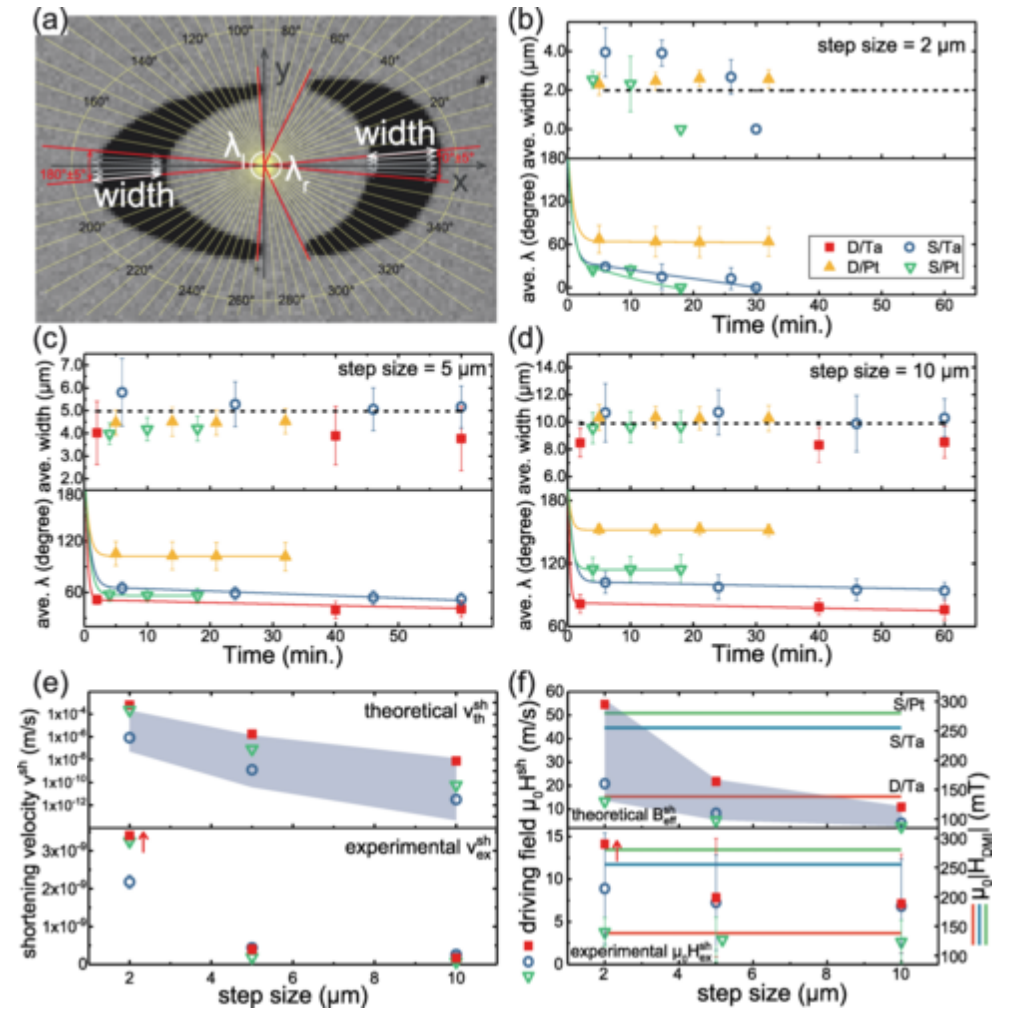

(a)
c
b
a
Na Bi
(b)
1
z (Å)
30 Å
(c)
Energy (meV)
700
600
500
400
300
200
-0.4 -0.2 0 0.2 0.4
q (1 / Å)
Na3Bi(1)
450 meV
500 meV
550 meV
600 meV
(d)
(e)
(f)
(g)
2σ
G-G0
-2σ
100 Å
(h)
(i)
(j)
(k)
high
PSD
low
0.2 / Å
(a)
c
b
a
Cd As
(b)
1
z (Å)
30 Å
(c)
Energy (meV)
600
500
400
300
200
100
0
-100
-0.4 -0.2 0 0.2 0.4
q (1 / Å)
Cd3As2
150 meV
250 meV
350 meV
450 meV
(d)
(e)
(f)
(g)
2σ
G-G0
-2σ
100 Å
(h)
(i)
(j)
(k)
high
PSD
low
0.2 / Å

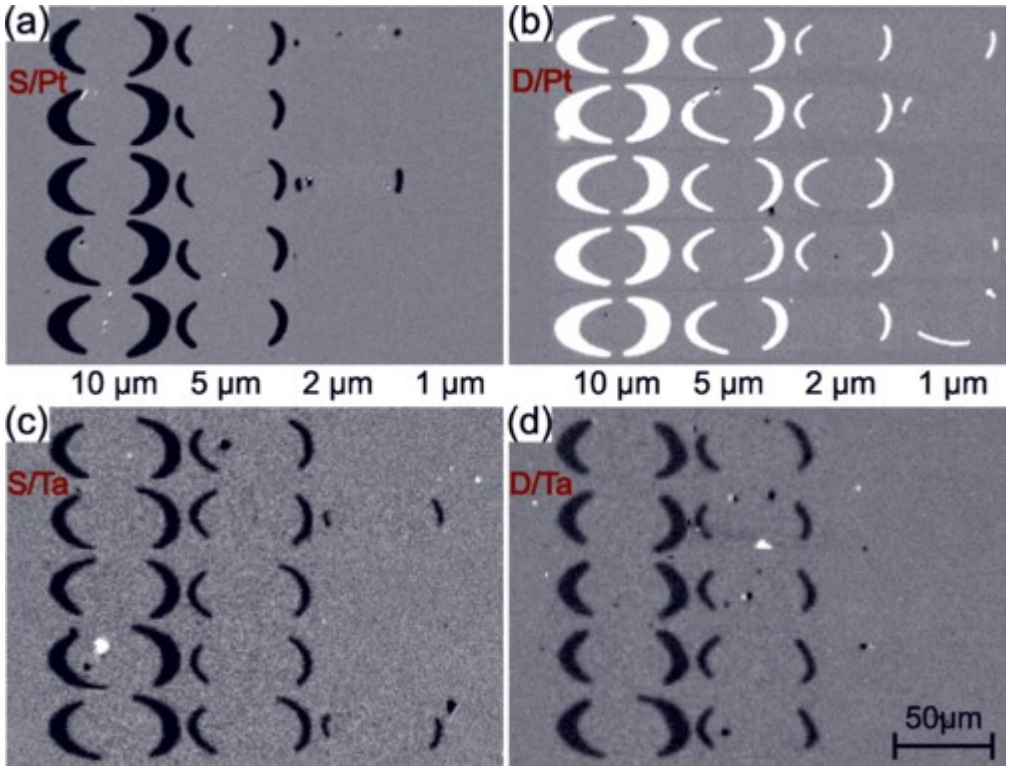

(a)
200μm

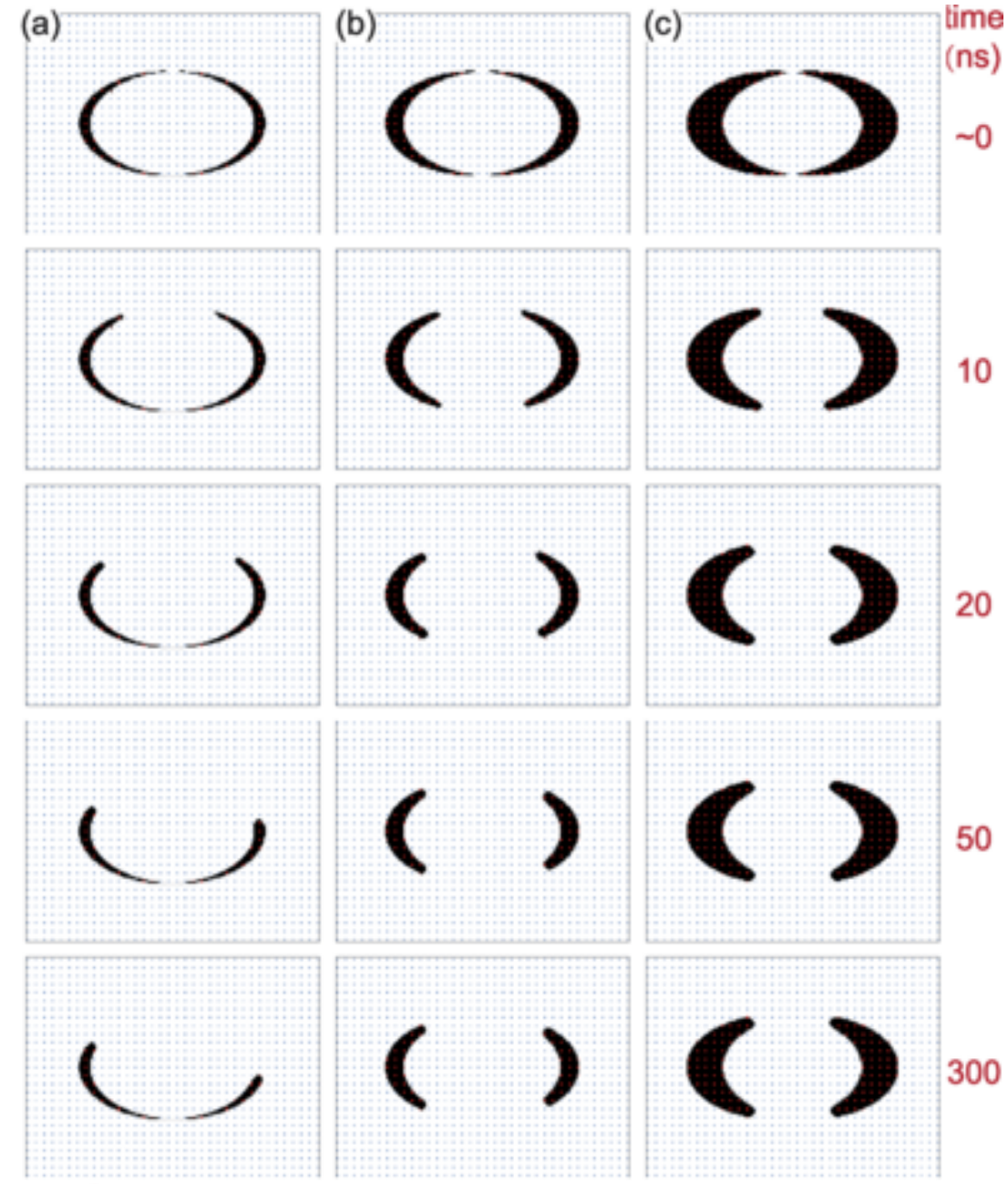

(b)
Area (x10-10 m2)
Pulse energy (nJ)
S/Pt
D/Pt
S/Ta
D/Ta

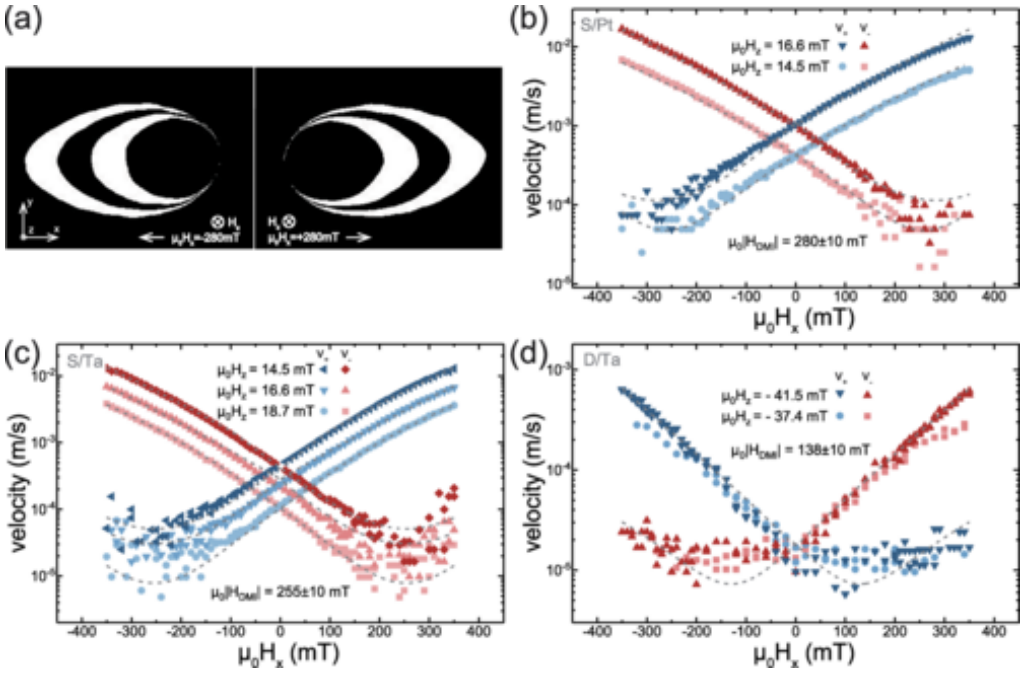

(a)
first pulse
second pulse
after ns
ΔS
R
φ
x
y

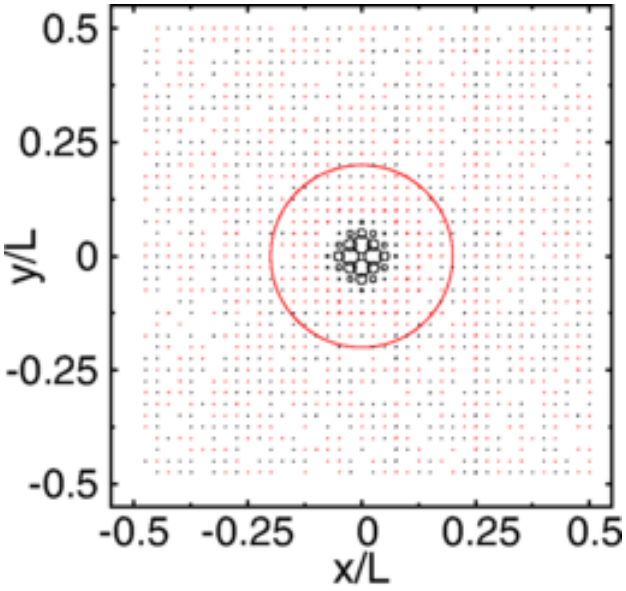

(b)
w'
w
θ
dx
(c)
w
dx

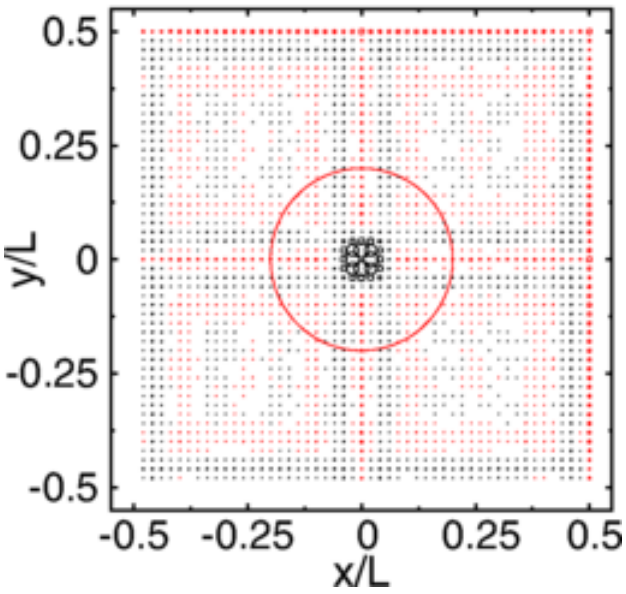

(a)
width
width
λl
λr
y
x
(b)
step size = 2 μm
ave. width (μm)
ave. λ (degree)
D/Ta
S/Ta
D/Pt
S/Pt
Time (min.)
(c)
step size = 5 μm
(d)
step size = 10 μm
(e)
theoretical v_th^sh
experimental v_ex^sh
shortening velocity v^sh (m/s)
step size (μm)
(f)
S/Pt
S/Ta
D/Ta
theoretical B_eff^sh
experimental μ0H_ex^sh
driving field μ0H^sh (m/s)
μ0|H_DMI| (mT)
step size (μm)

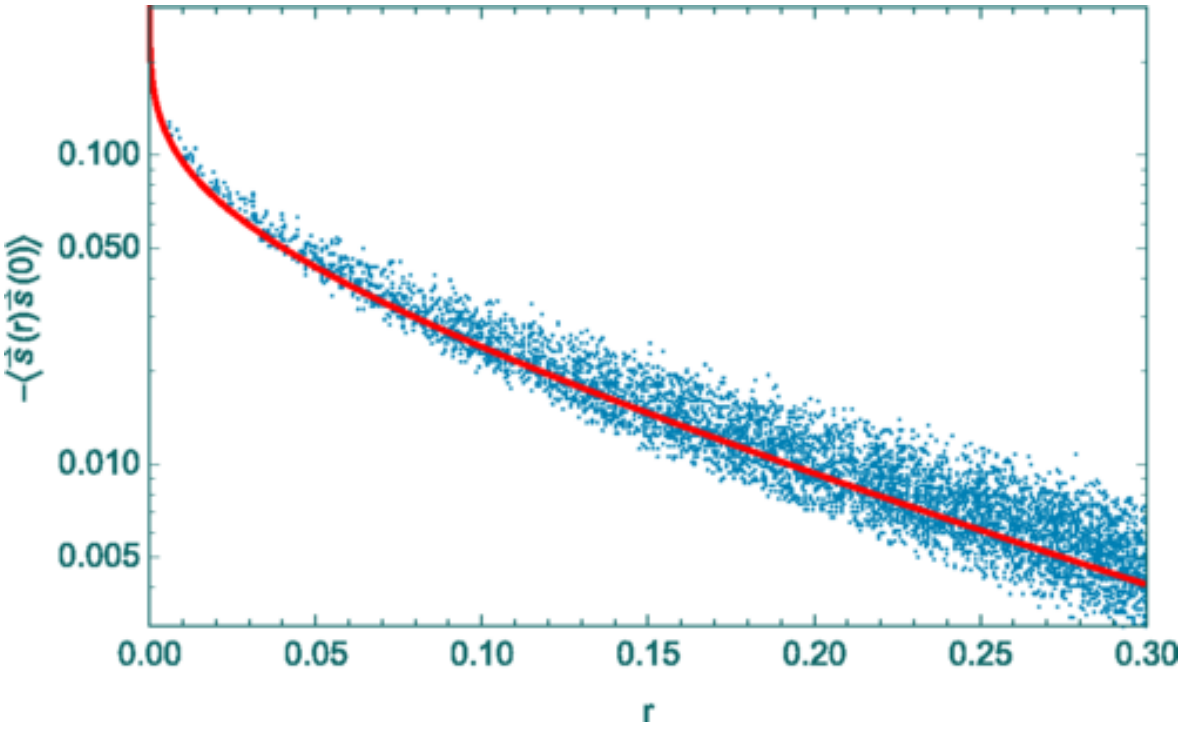

(a)
S/Pt
(b)
D/Pt
10 μm 5 μm 2 μm 1 μm
10 μm 5 μm 2 μm 1 μm
(c)
S/Ta
(d)
D/Ta
50μm

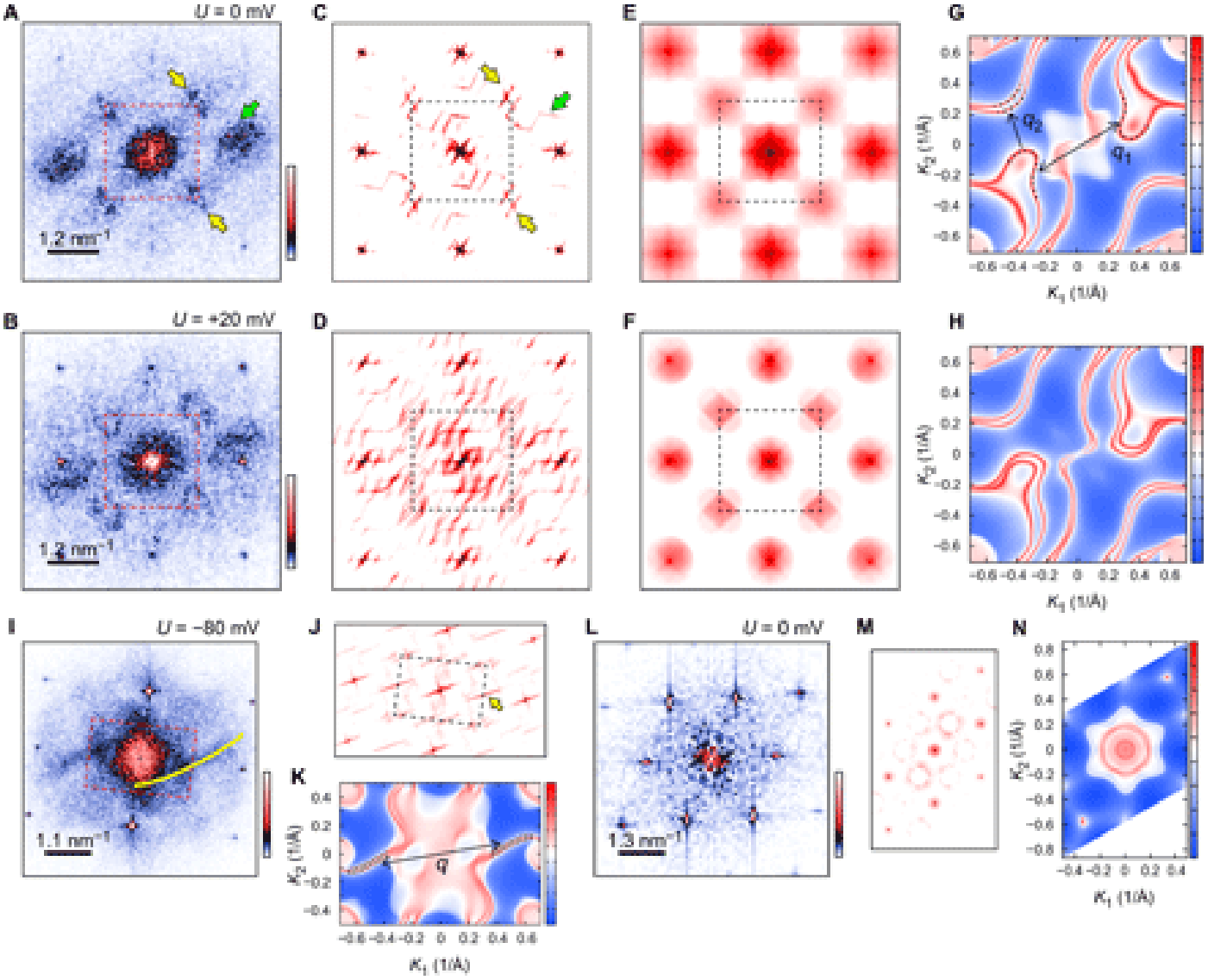

(a)
(b)
(c)
time (ns)
~0
10
20
50
300
step size (μm)
2
5
10

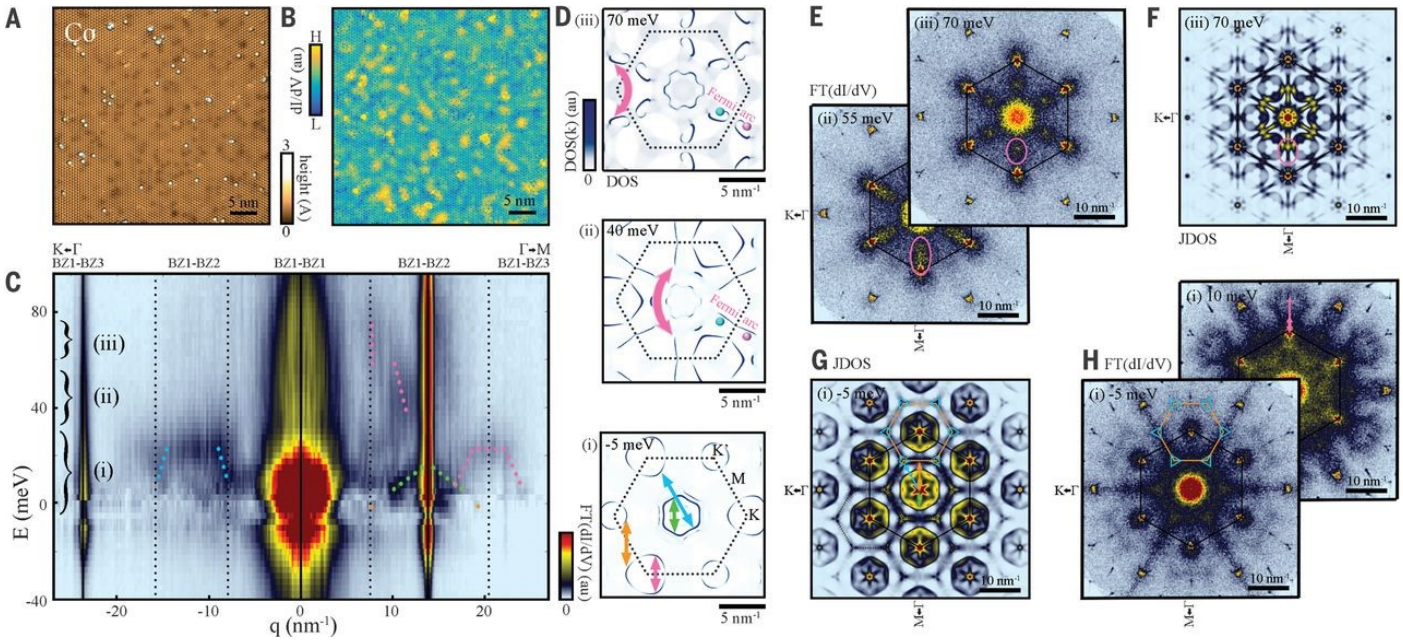

(a)
(b)
S/Pt
μ0Hz = 16.6 mT
μ0Hz = 14.5 mT
μ0|HDMI| = 280±10 mT
velocity (m/s)
μ0Hx (mT)
(c)
S/Ta
μ0Hz = 14.5 mT
μ0Hz = 16.6 mT
μ0Hz = 18.7 mT
μ0|HDMI| = 255±10 mT
(d)
D/Ta
μ0Hz = - 41.5 mT
μ0Hz = - 37.4 mT
μ0|HDMI| = 138±10 mT

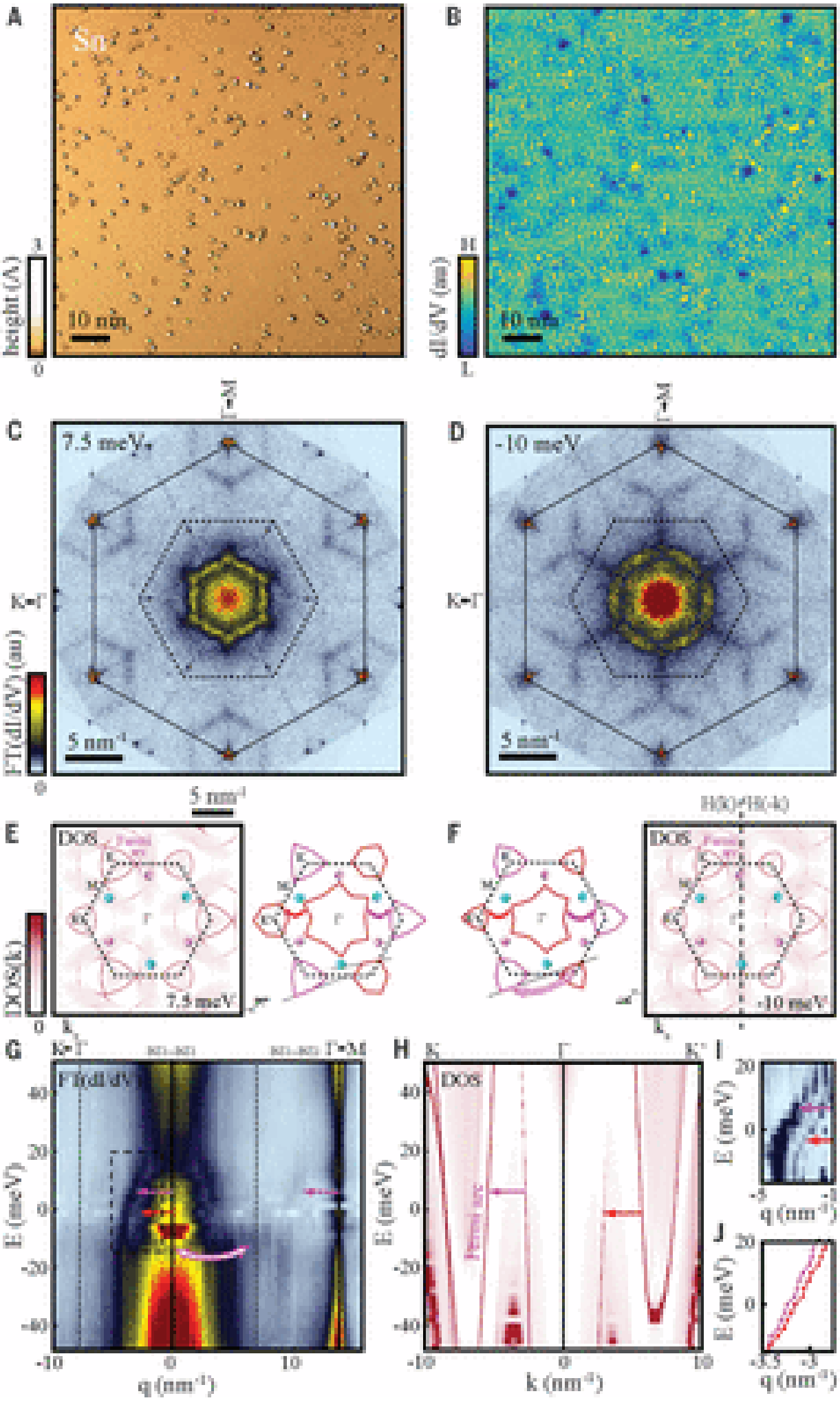

0.5
0.25
0
-0.25
-0.5
y/L
-0.5 -0.25 0 0.25 0.5
x/L

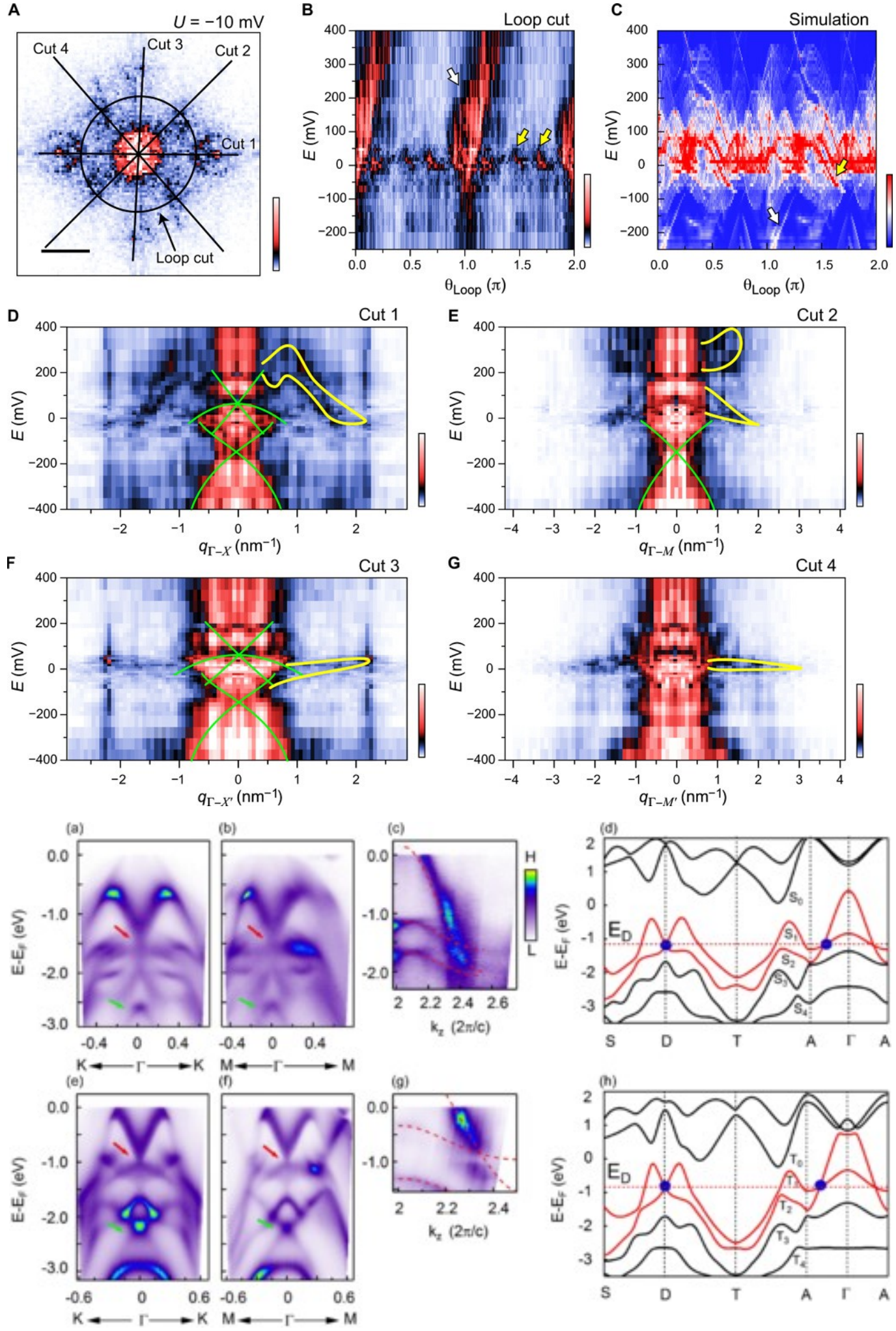

0.5
0.25
0
-0.25
-0.5
y/L
-0.5 -0.25 0 0.25 0.5
x/L

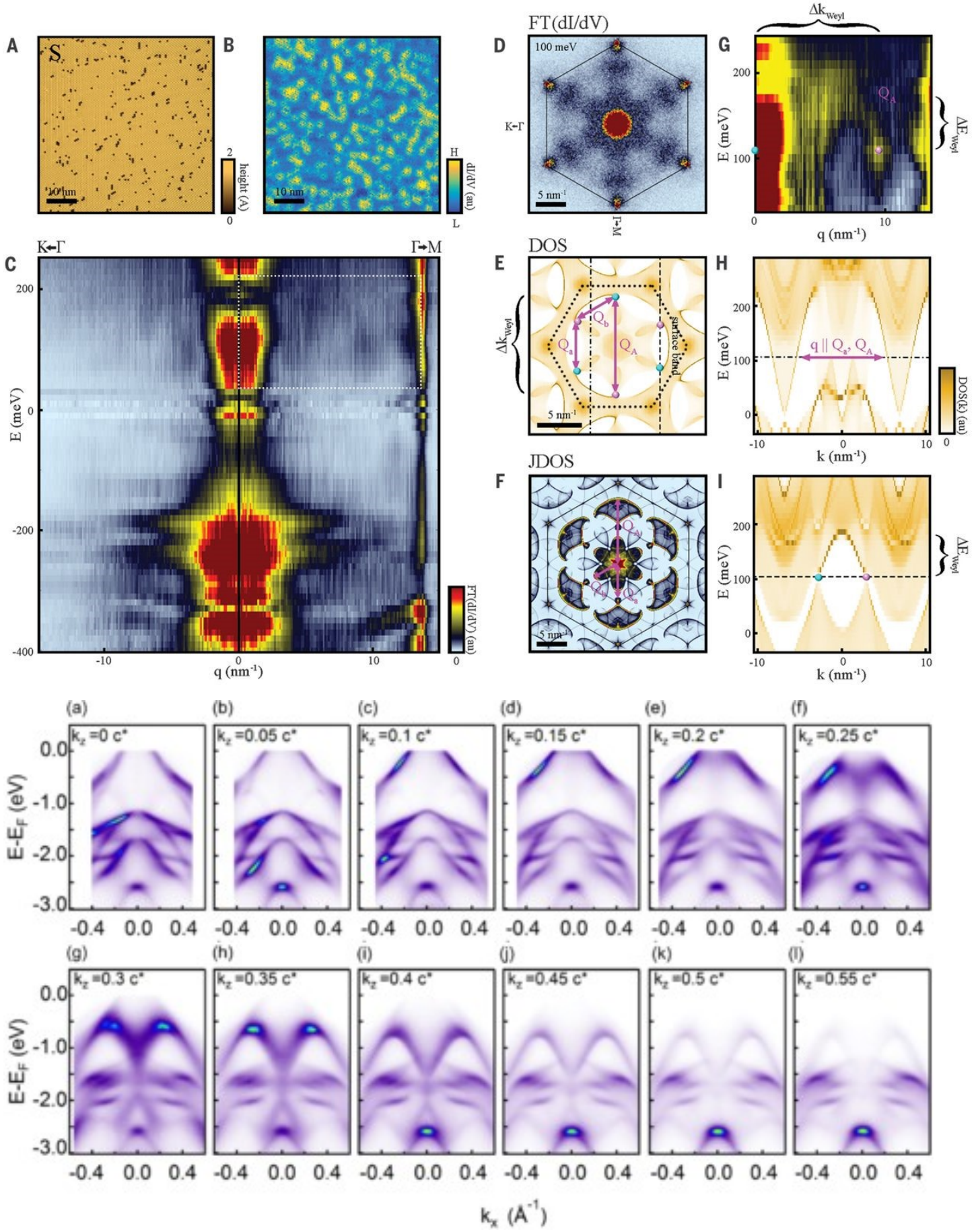

0.100
0.050
0.010
0.005
$-\langle \hat{s}(r)\hat{s}(0)\rangle$
0.00 0.05 0.10 0.15 0.20 0.25 0.30
r


A
U = 0 mV
1.2 nm⁻¹
B
U = +20 mV
1.2 nm⁻¹
C
D
E
F
G
q2
q1
K2 (1/Å)
K1 (1/Å)
H
I
U = −80 mV
1.1 nm⁻¹
J
K
q
K2 (1/Å)
K1 (1/Å)
L
U = 0 mV
1.3 nm⁻¹
M
N
K2 (1/Å)
K1 (1/Å)

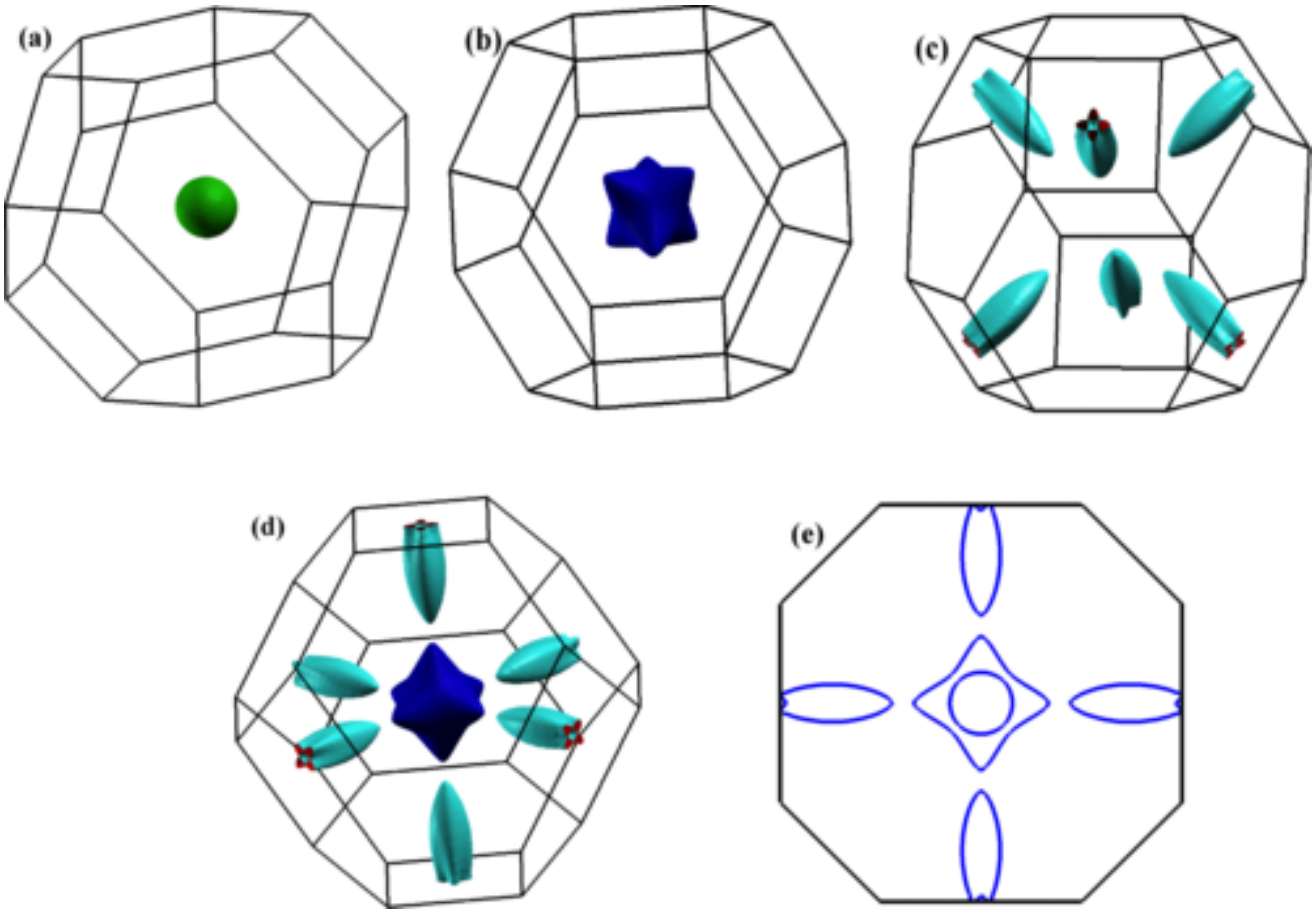

A
Co
5 nm
B
H
L
dI/dV (au)
3
0
height (Å)
5 nm
C
K→Γ
BZ1-BZ3
BZ1-BZ2
BZ1-BZ1
BZ1-BZ2
Γ→M
BZ1-BZ3
(iii)
(ii)
(i)
E (meV)
q (nm⁻¹)
D
(iii) 70 meV
Fermi arc
DOS(k) (au)
0
DOS
5 nm⁻¹
(ii) 40 meV
Fermi arc
5 nm⁻¹
(i) -5 meV
K
M
K
FT(dI/dV) (au)
0
5 nm⁻¹
E
FT(dI/dV)
(iii) 70 meV
(ii) 55 meV
K→Γ
M→Γ
10 nm⁻¹
F
(iii) 70 meV
K→Γ
JDOS
M→Γ
10 nm⁻¹
G
JDOS
(i) -5 meV
K→Γ
M→Γ
10 nm⁻¹
H
FT(dI/dV)
(i) 10 meV
(i) -5 meV
K→Γ
M→Γ
10 nm⁻¹

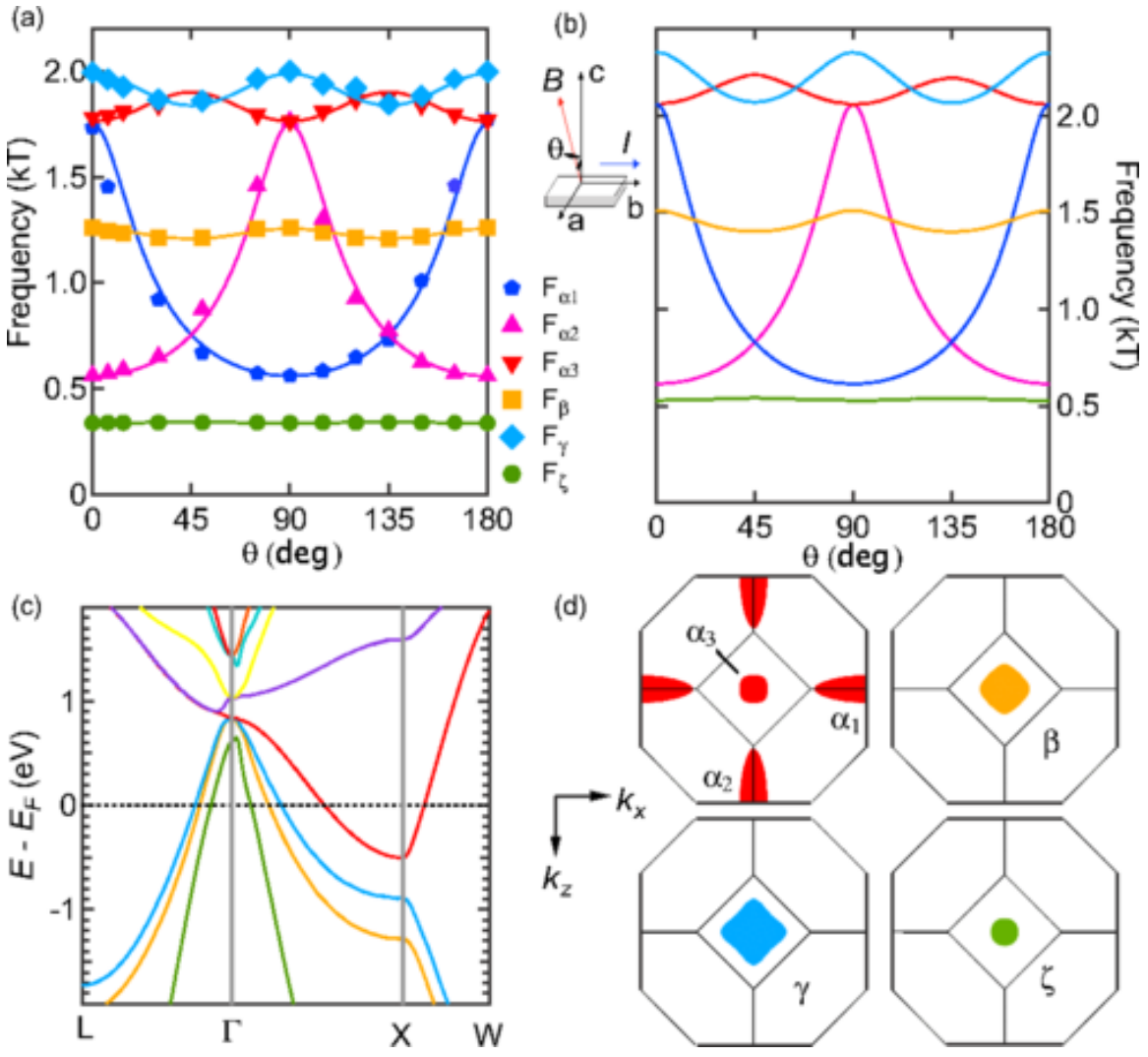

A
Sn
height (Å)
10 nm
B
dI/dV (au)
10 nm
C
Γ-M
7.5 meV
K-Γ
FT(dI/dV) (au)
5 nm⁻¹
D
-10 meV
5 nm⁻¹
E
DOS
DOS(k)
7.5 meV
F
DOS
-10 meV
G
K-Γ
FT(dI/dV)
E (meV)
q (nm⁻¹)
H
K
Γ
K'
DOS
Fermi arc
E (meV)
k (nm⁻¹)
I
E (meV)
q (nm⁻¹)
J
E (meV)
q (nm⁻¹)

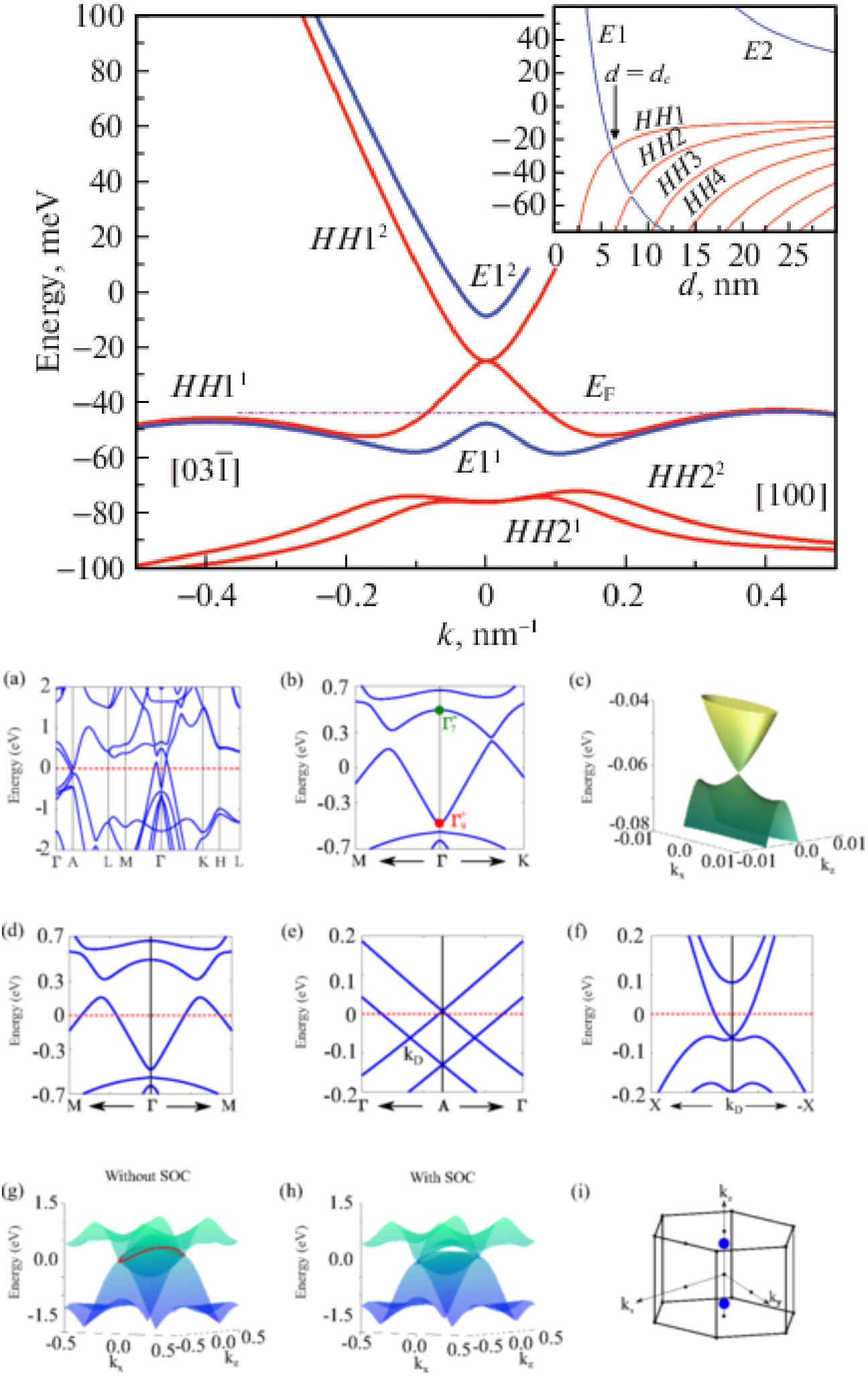

A
U = −10 mV
Cut 4
Cut 3
Cut 2
Cut 1
Loop cut
B
Loop cut
E (mV)
θLoop (π)
C
Simulation
E (mV)
θLoop (π)
D
Cut 1
E (mV)
qΓ–X (nm−1)
E
Cut 2
E (mV)
qΓ–M (nm−1)
F
Cut 3
E (mV)
qΓ–X′ (nm−1)
G
Cut 4
E (mV)
qΓ–M′ (nm−1)
(a)
(b)
(c)
(d)
E-EF (eV)
K Γ K
M Γ M
kz (2π/c)
H
L
ED
S0
S1
S2
S3
S4
S D T A Γ A
(e)
(f)
(g)
(h)
T0
T1
T2
T3
T4

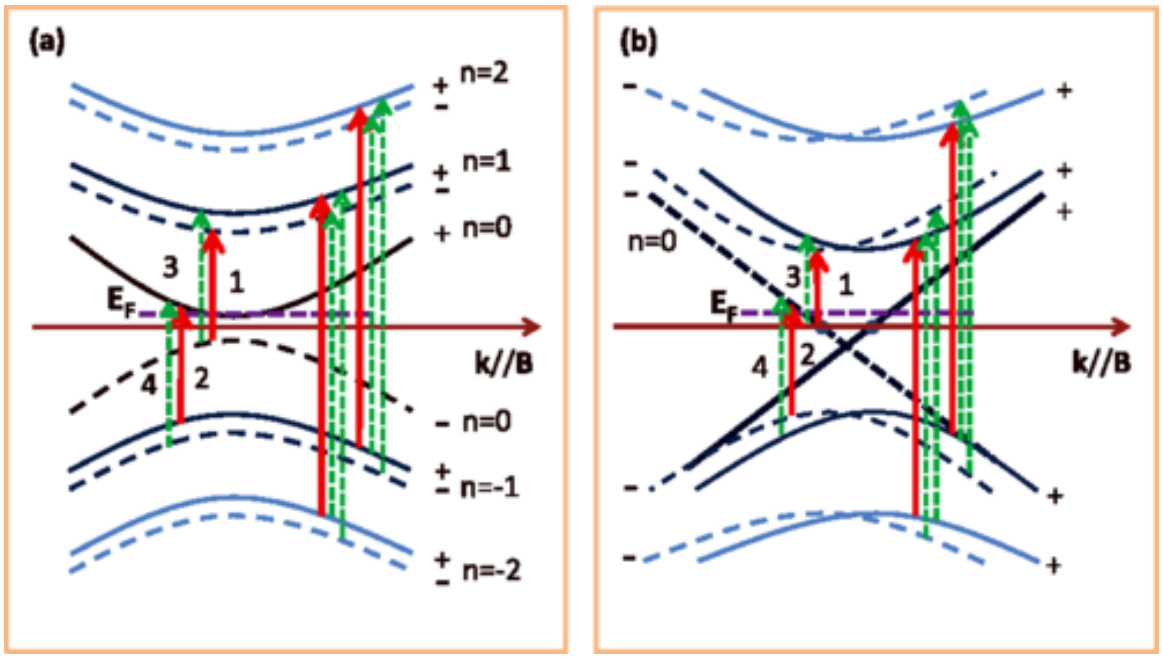

A
S
10 nm
2
height (A)
0
B
10 nm
H
dI/dV (au)
L
C
K←Γ
Γ→M
200
0
-200
-400
E (meV)
-10
0
10
q (nm-1)
FT(dI/dV) (au)
0
FT(dI/dV)
D
100 meV
K←Γ
M←Γ
5 nm-1
DOS
E
Δkweyl
Qb
Qa
QA
surface band
5 nm-1
JDOS
F
QW
Qa
QA
5 nm-1
Δkweyl
G
200
100
E (meV)
QA
ΔEweyl
0
10
q (nm-1)
H
200
100
0
E (meV)
q || Qa, QA
DOS(k) (au)
0
-10
0
10
k (nm-1)
I
200
100
0
E (meV)
ΔEweyl
-10
0
10
k (nm-1)

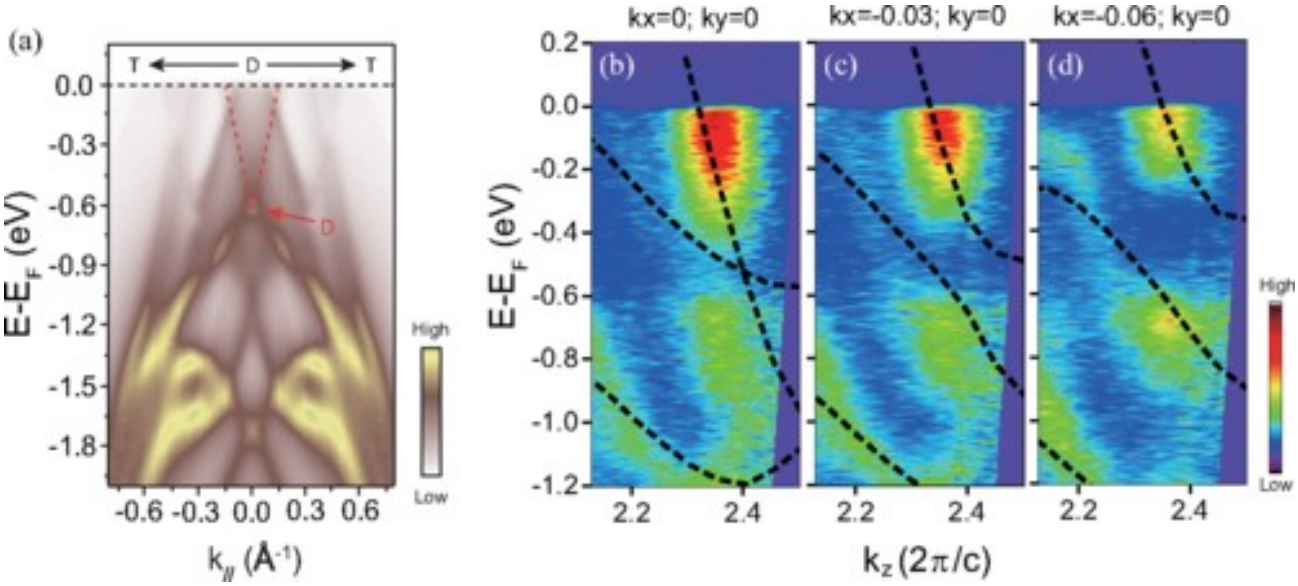
(a) kz =0 c*
(b) kz =0.05 c*
(c) kz =0.1 c*
(d) kz =0.15 c*
(e) kz =0.2 c*
(f) kz =0.25 c*
(g) kz =0.3 c*
(h) kz =0.35 c*
(i) kz =0.4 c*
(j) kz =0.45 c*
(k) kz =0.5 c*
(l) kz =0.55 c*
E-EF (eV)
0.0
-1.0
-2.0
-3.0
-0.4
0.0
0.4
kx (Å-1)

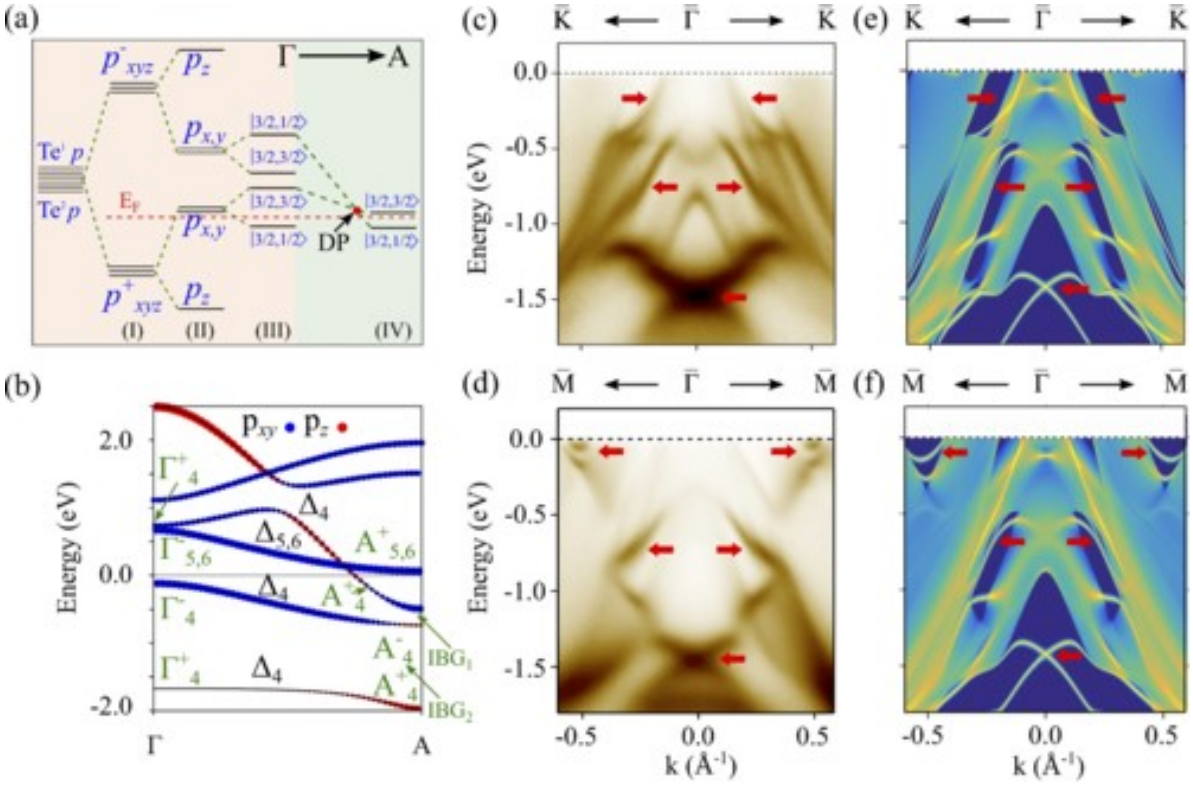

(a)
(b)
(c)
(d)
(e)

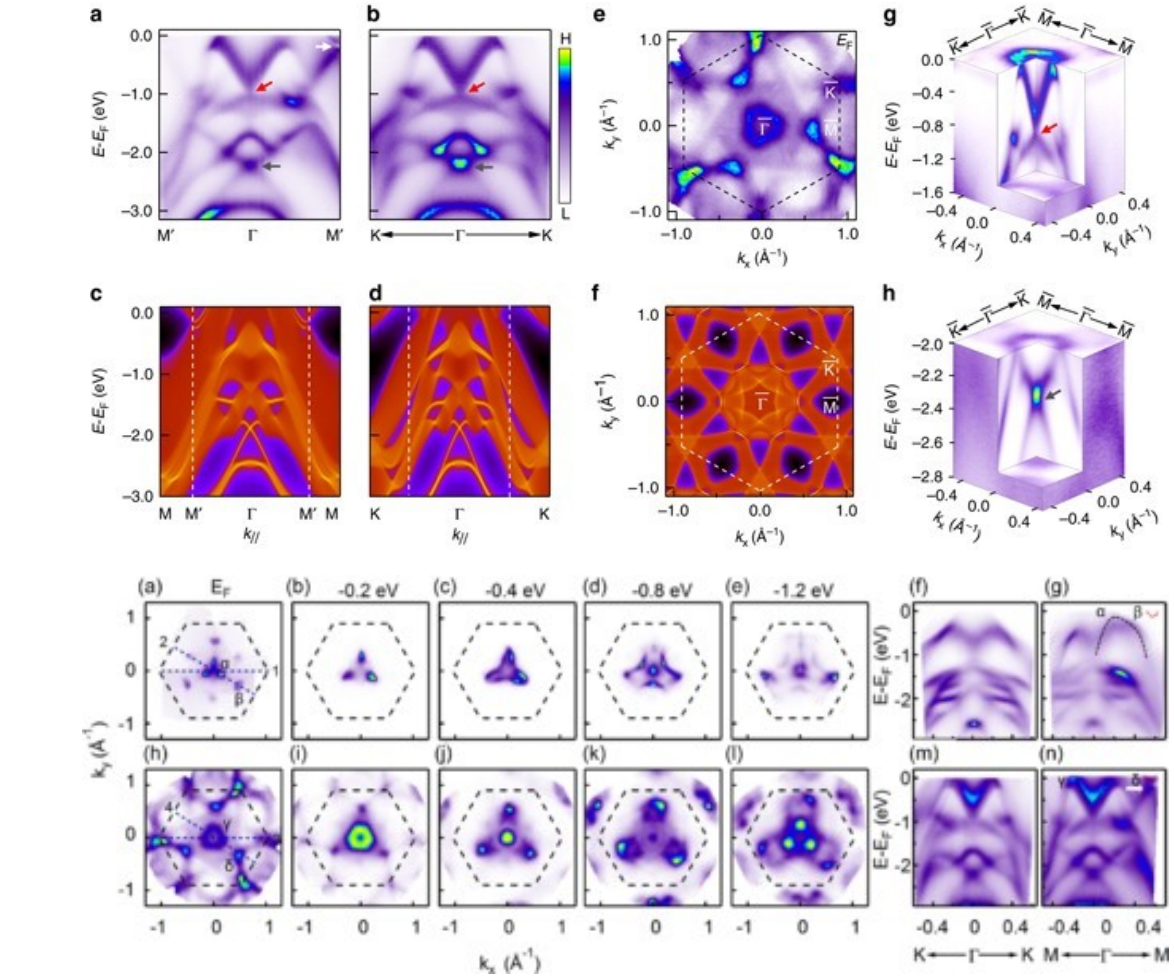

(a)
Frequency (kT)
θ (deg)
$F_{\alpha 1}$
$F_{\alpha 2}$
$F_{\alpha 3}$
F_{β}
F_{γ}
F_{ζ}
(b)
B
c
θ
l
a
b
Frequency (kT)
θ (deg)
(c)
E - E_F (eV)
L
Γ
X
W
(d)
α_3
α_1
α_2
k_x
k_z
β
γ
ζ

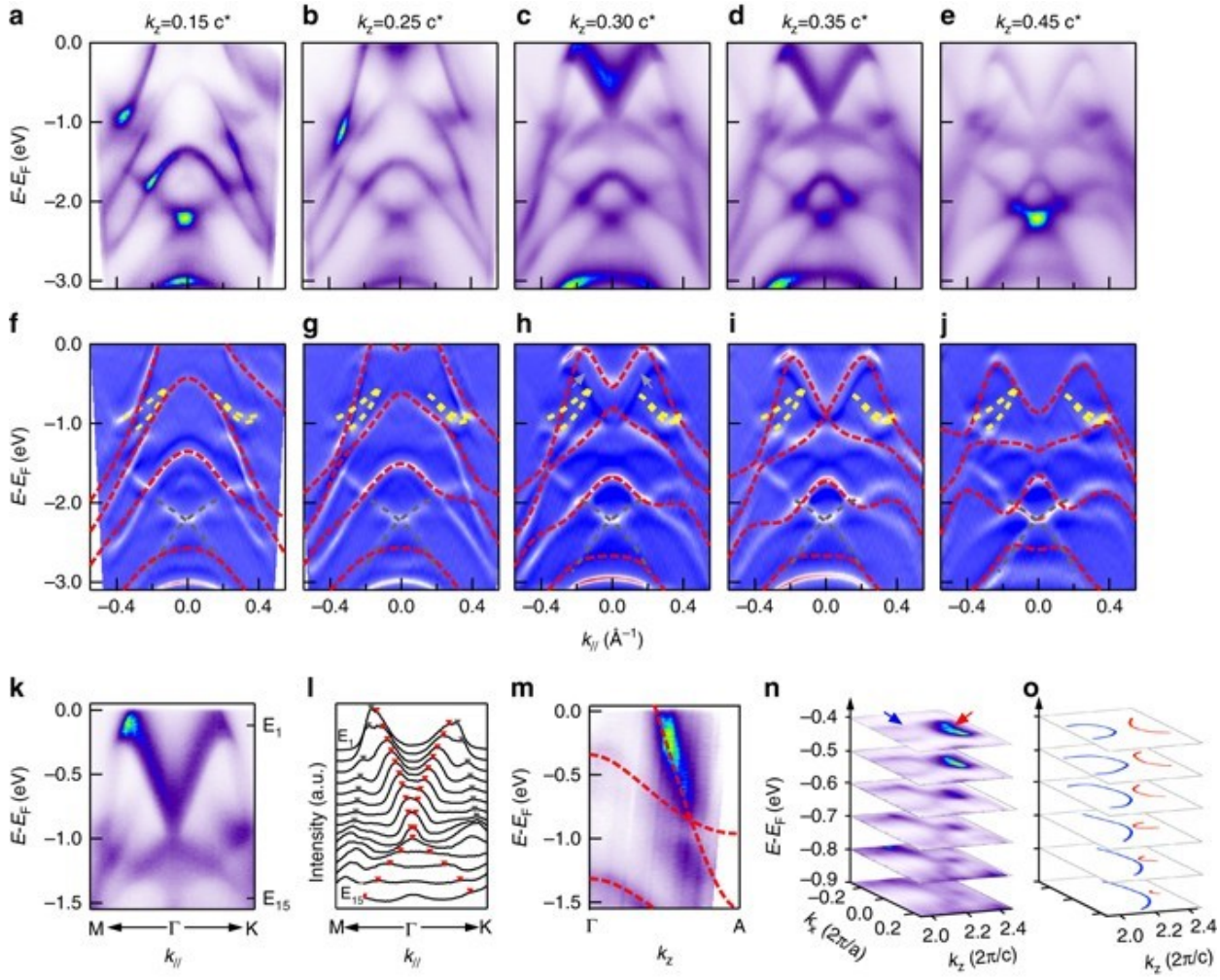

Energy, meV
k, nm⁻¹
HH1²
E1²
HH1¹
E1¹
E_F
HH2²
HH2¹
[03̄1]
[100]
E1
E2
d = d_c
HH1
HH2
HH3
HH4
d, nm
(a)
(b)
(c)
(d)
(e)
(f)
(g)
(h)
(i)
Without SOC
With SOC
Γ A L M Γ K H L
M Γ M
M Γ K
Γ A Γ
X k_D -X
k_D
Γ₇⁻
Γ₆⁺
k_x
k_z

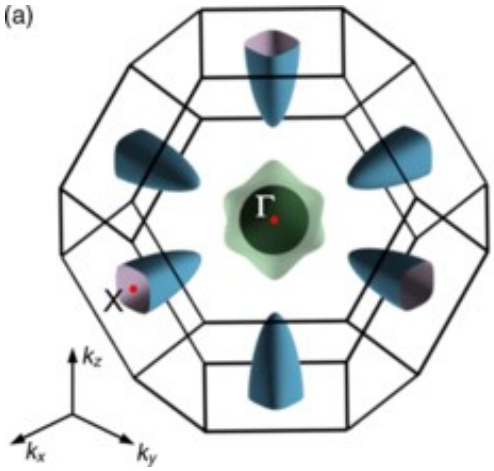

(a)
n=2
n=1
n=0
n=0
n=-1
n=-2
E_F
k//B
1
2
3
4
(b)
n=0
E_F
k//B
1
2
3
4

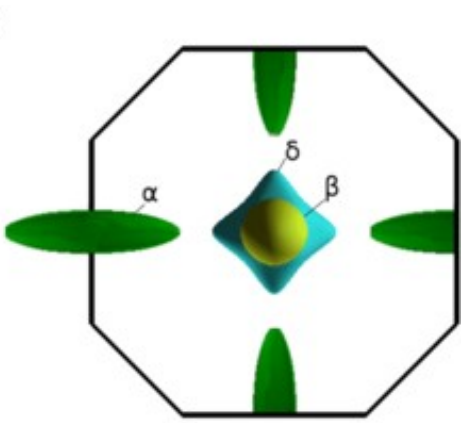

(a)
T
D
T
E-E_F (eV)
k_// (Å^-1)
High
Low
kx=0; ky=0
kx=-0.03; ky=0
kx=-0.06; ky=0
(b)
(c)
(d)
E-E_F (eV)
k_z (2π/c)
High
Low

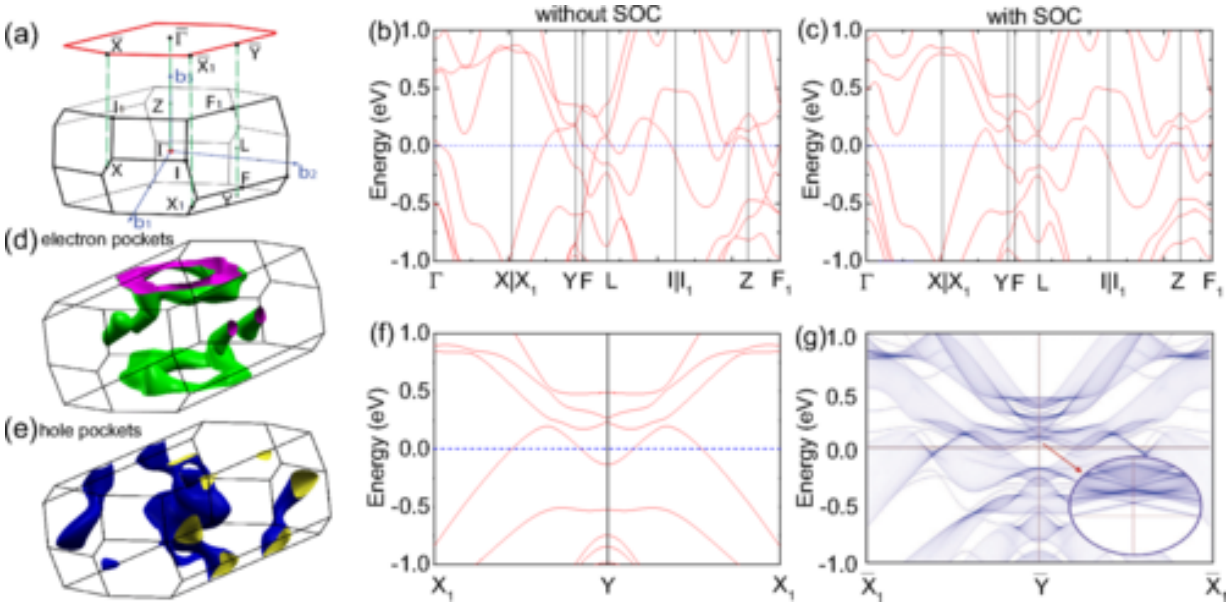

(a)
Γ
A
Te' p
Te' p
E_F
DP
(I)
(II)
(III)
(IV)
(b)
p_xy
p_z
Energy (eV)
Γ
A
IBG_1
IBG_2
(c)
K̄
Γ̄
K̄
Energy (eV)
(d)
M̄
Γ̄
M̄
k (Å^-1)
(e)
K̄
Γ̄
K̄
(f)
M̄
Γ̄
M̄
k (Å^-1)

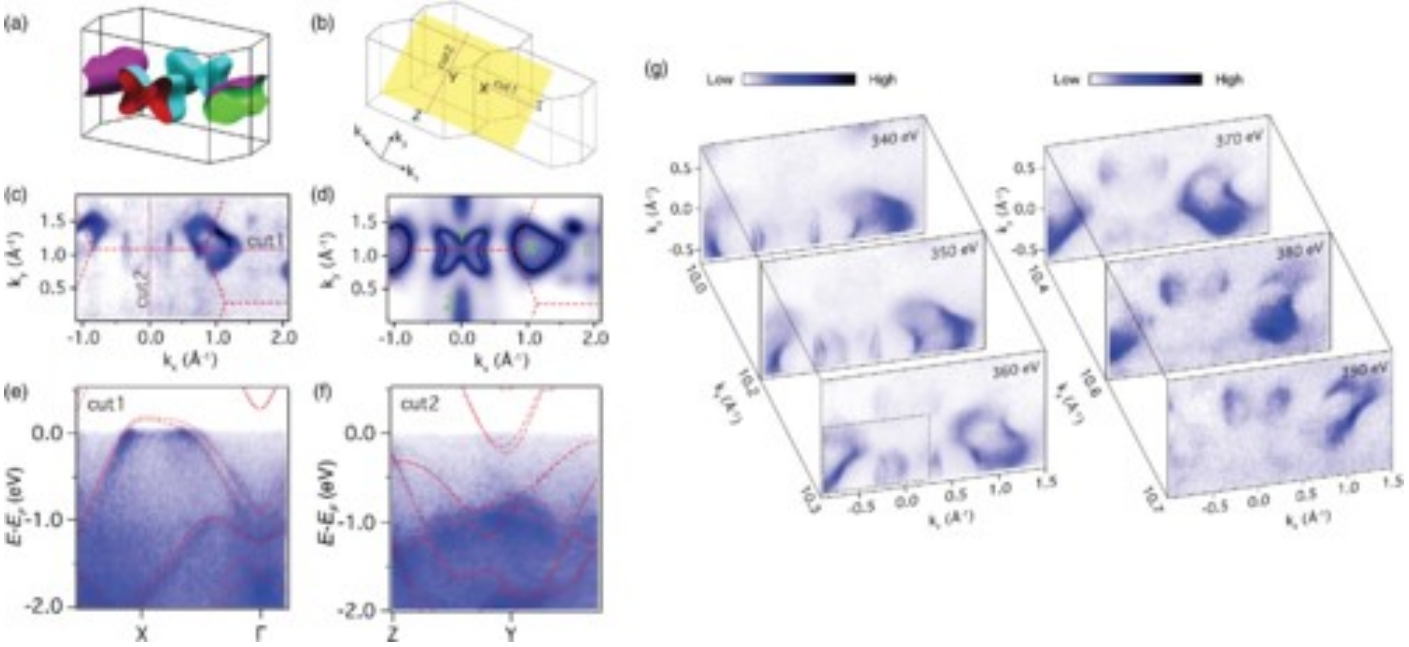

a
b
e
g
c
d
f
h
E-E_F (eV)
M′ Γ M′
K Γ K
k_y (Å^-1)
k_x (Å^-1)
k_x (Å^-1)
k_y (Å^-1)
k_//
H
L
(a) E_F
(b) -0.2 eV
(c) -0.4 eV
(d) -0.8 eV
(e) -1.2 eV
(f)
(g)
(h)
(i)
(j)
(k)
(l)
(m)
(n)
α
β
γ
δ
k_x (Å^-1)
K Γ K M Γ M

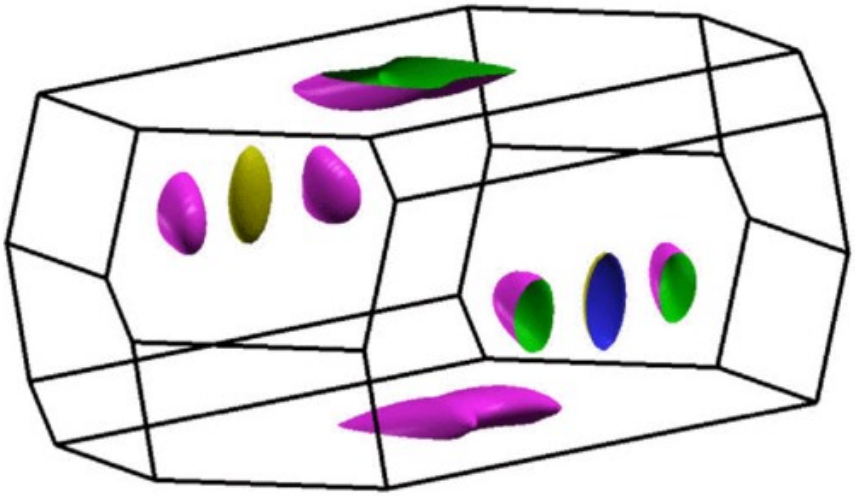

a
b
c
d
e
k_z=0.15 c*
k_z=0.25 c*
k_z=0.30 c*
k_z=0.35 c*
k_z=0.45 c*
f
g
h
i
j
E-E_F (eV)
k_// (Å^-1)
k
l
m
n
o
E_1
E_15
Intensity (a.u.)
M Γ K
Γ A
k_z
k_x (2π/a)
k_z (2π/c)

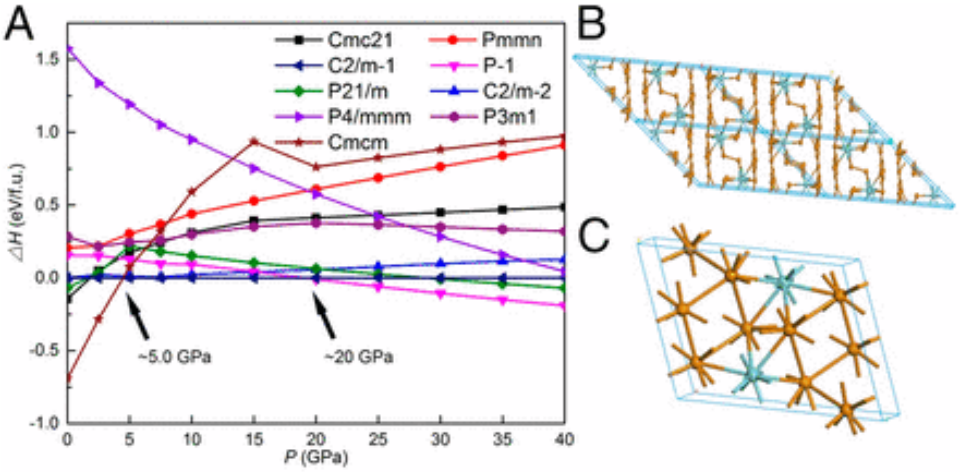

(a)
Γ
X
k_z
k_x
k_y

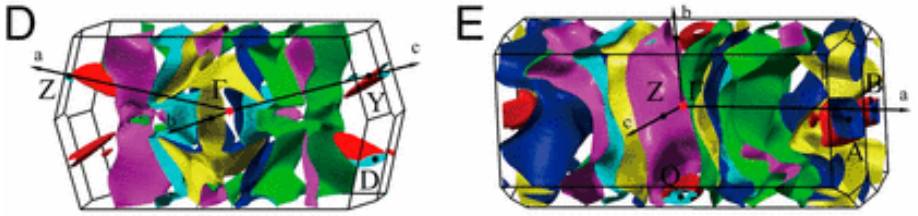

(b)
δ
α
β

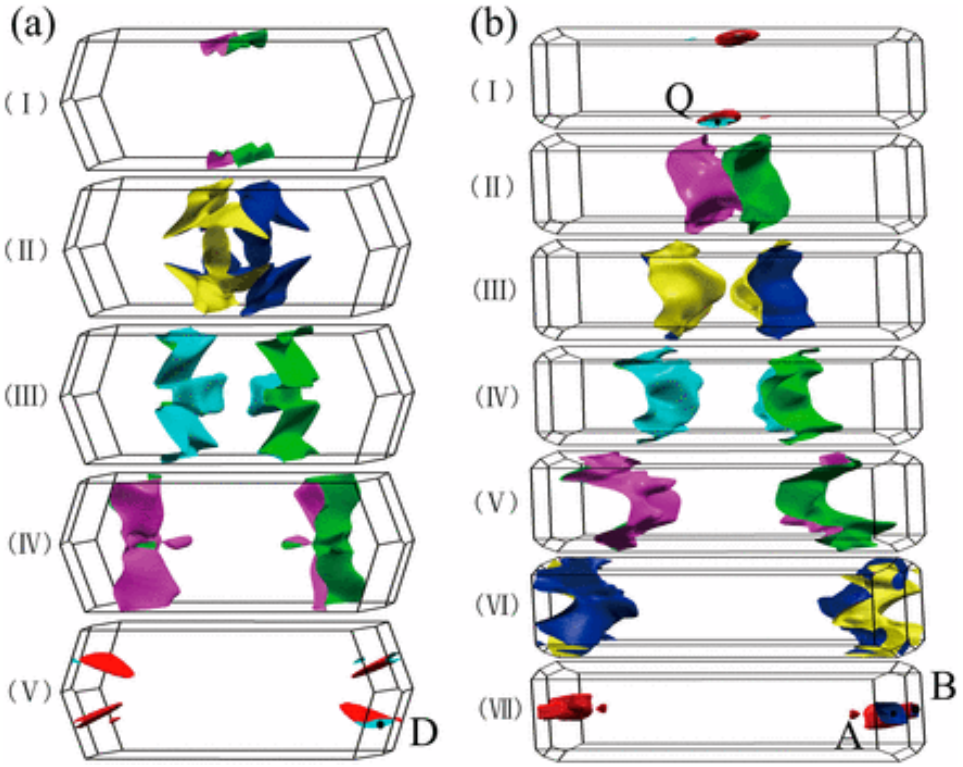

(a)
(b)
without SOC
(c)
with SOC
Energy (eV)
Γ
X|X1
YF
L
I|I1
Z
F1
(d) electron pockets
(e) hole pockets
(f)
(g)
X1
Y

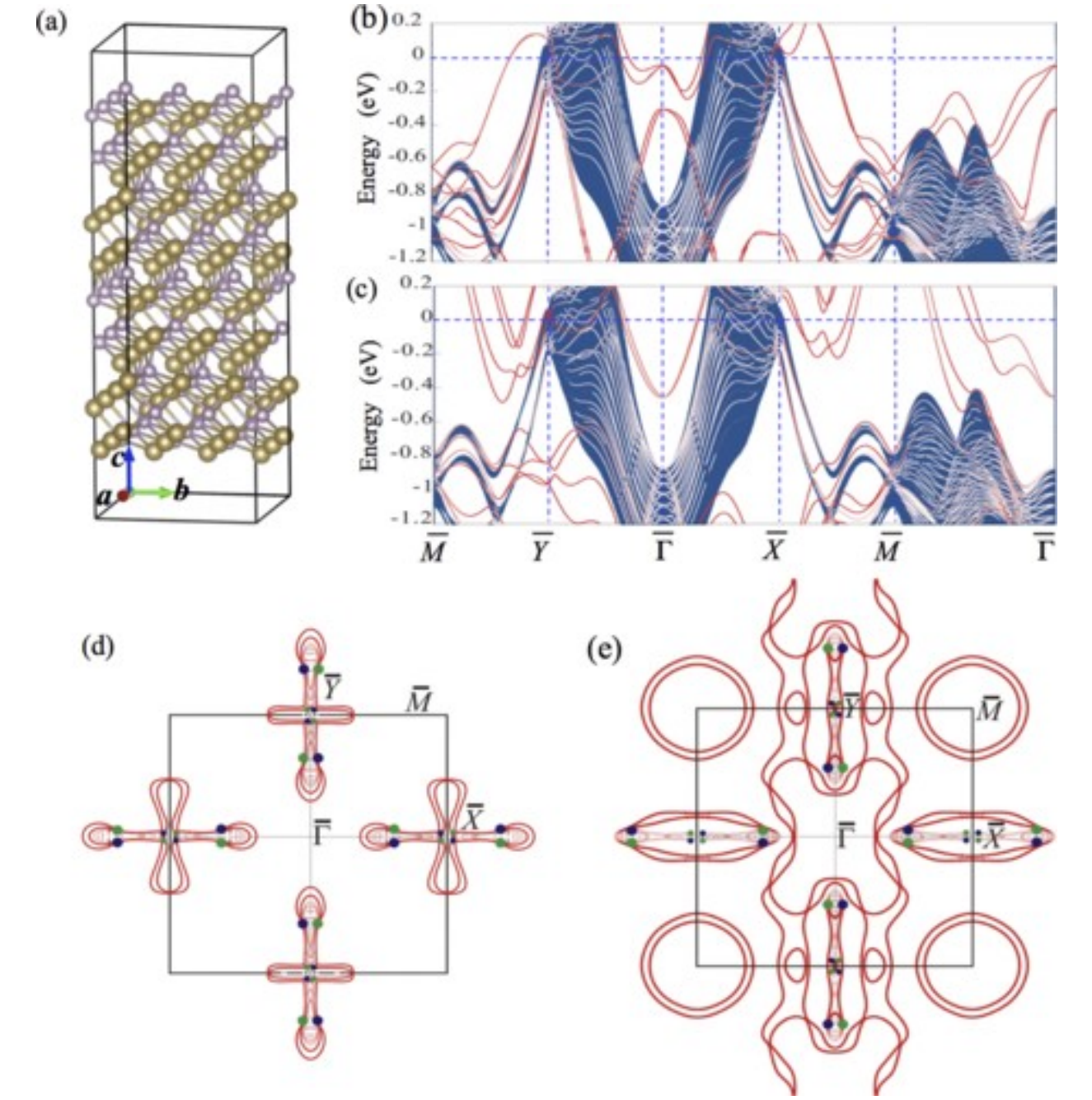

(a)
(b)
(c)
(d)
(e)
(f)
(g)
cut1
cut2
Low
High
340 eV
350 eV
360 eV
370 eV
380 eV
390 eV

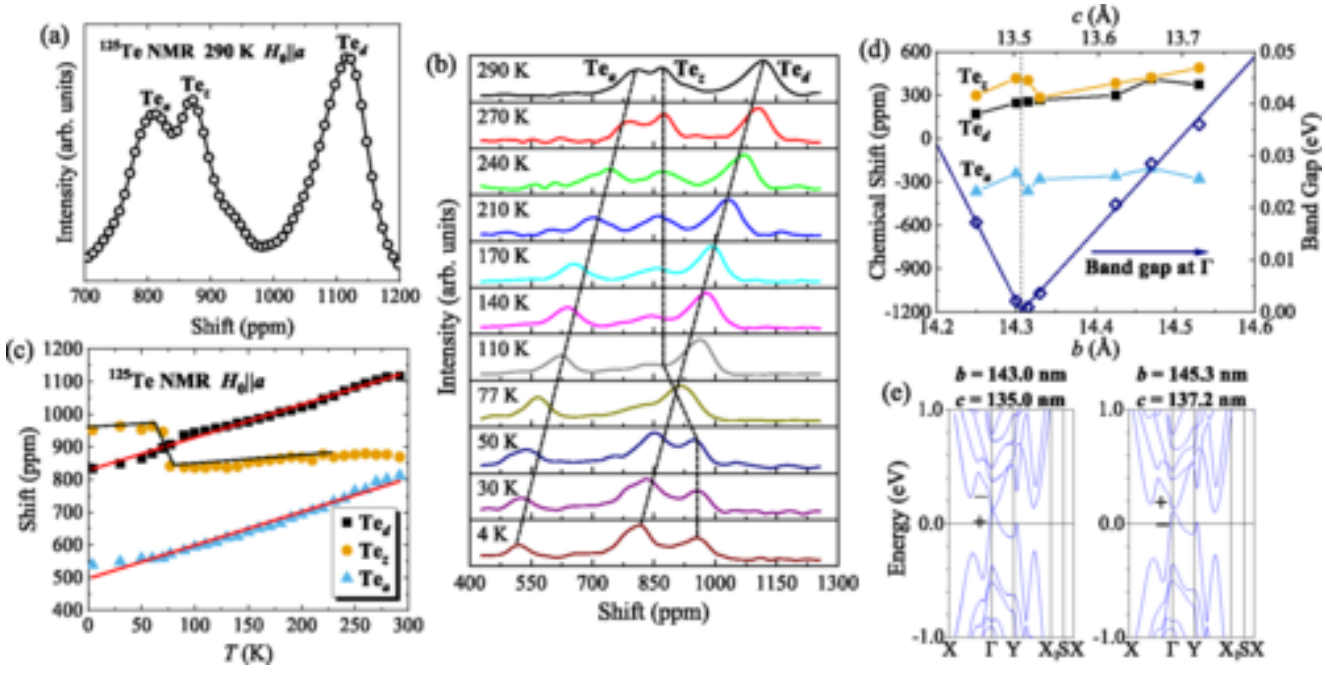


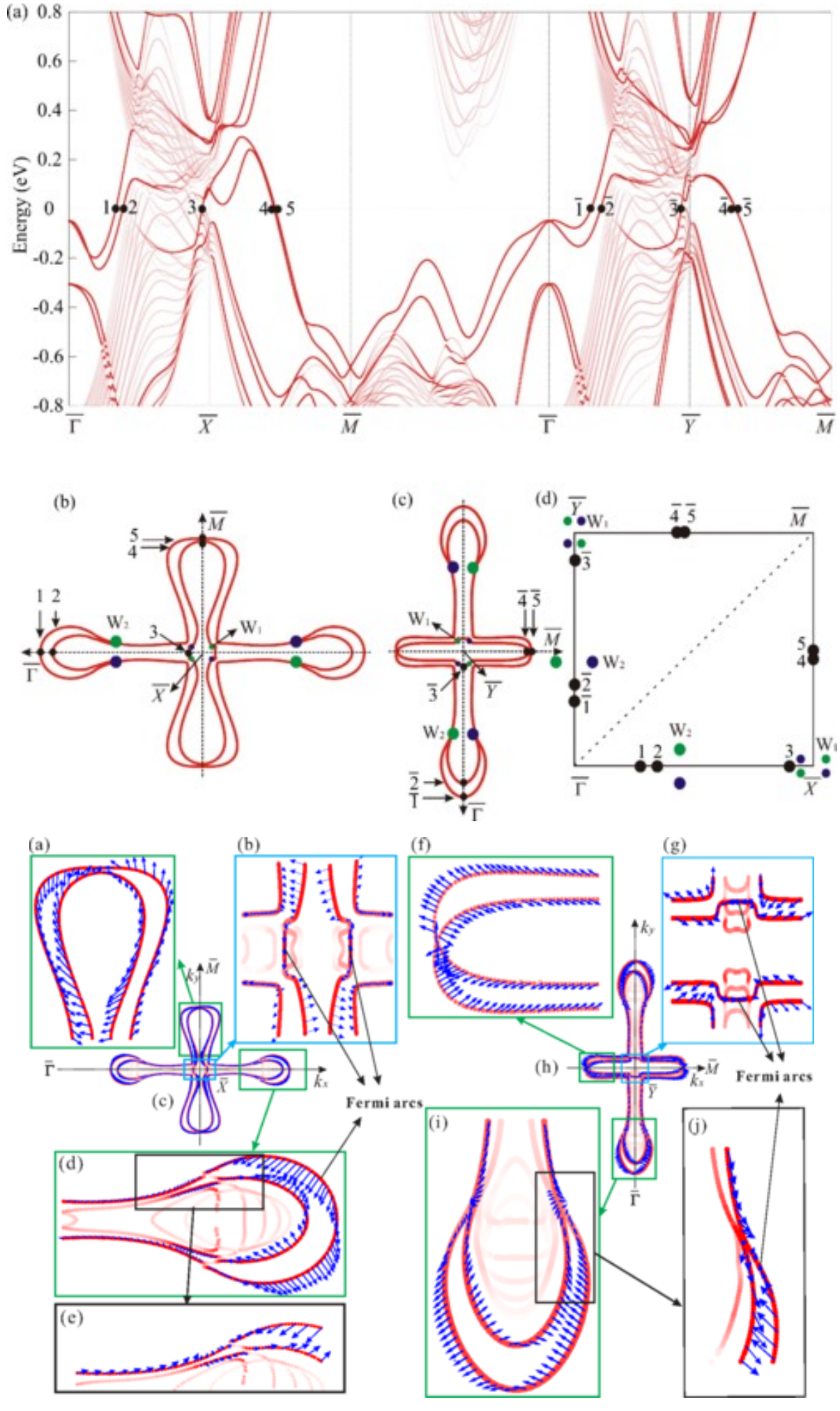

A
B
C
Cmc21
C2/m-1
P21/m
P4/mmm
Cmcm
Pmmn
P-1
C2/m-2
P3m1
△H (eV/f.u.)
P (GPa)
~5.0 GPa
~20 GPa

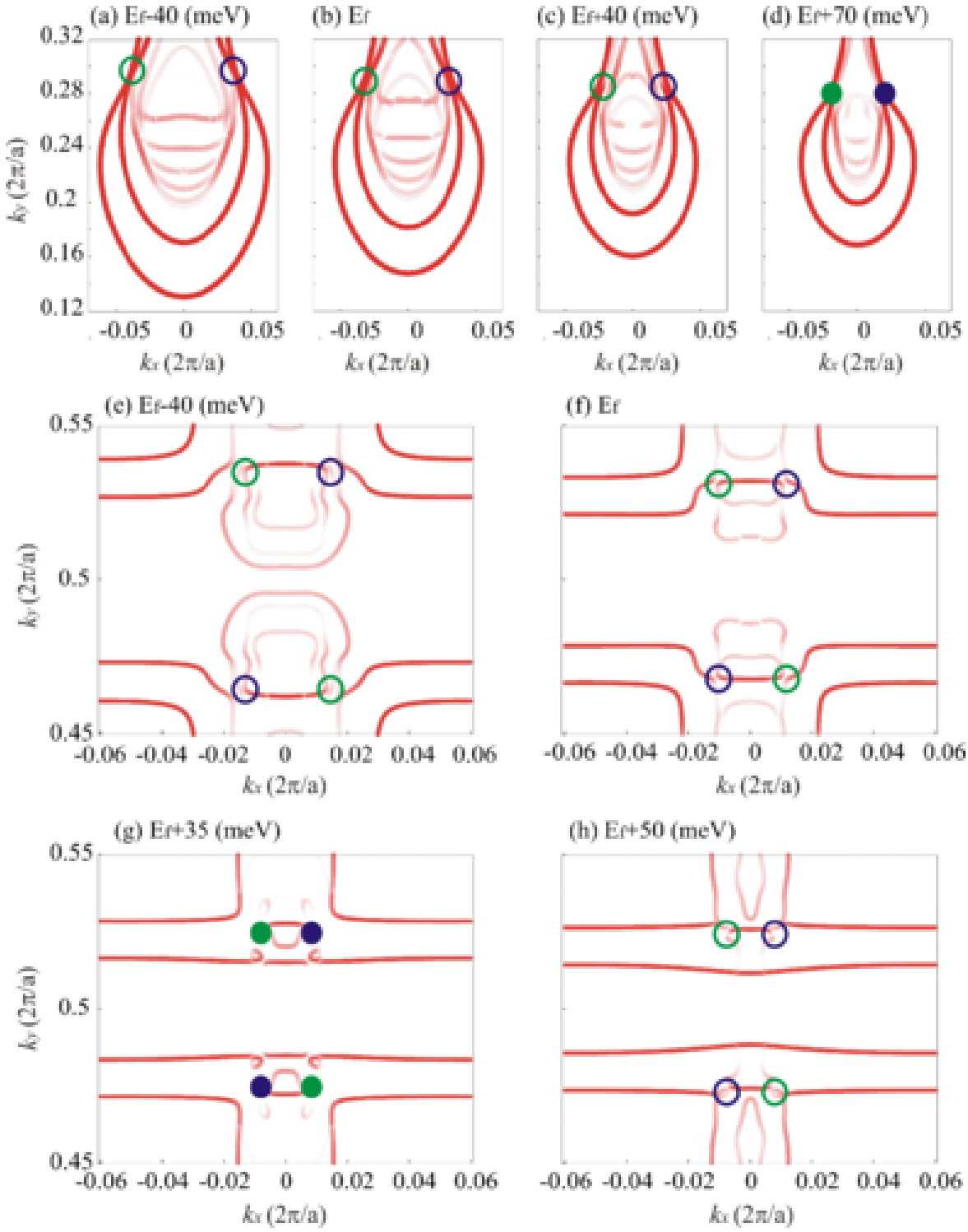

D
E
Z
Γ
Y
D
Q
A
B

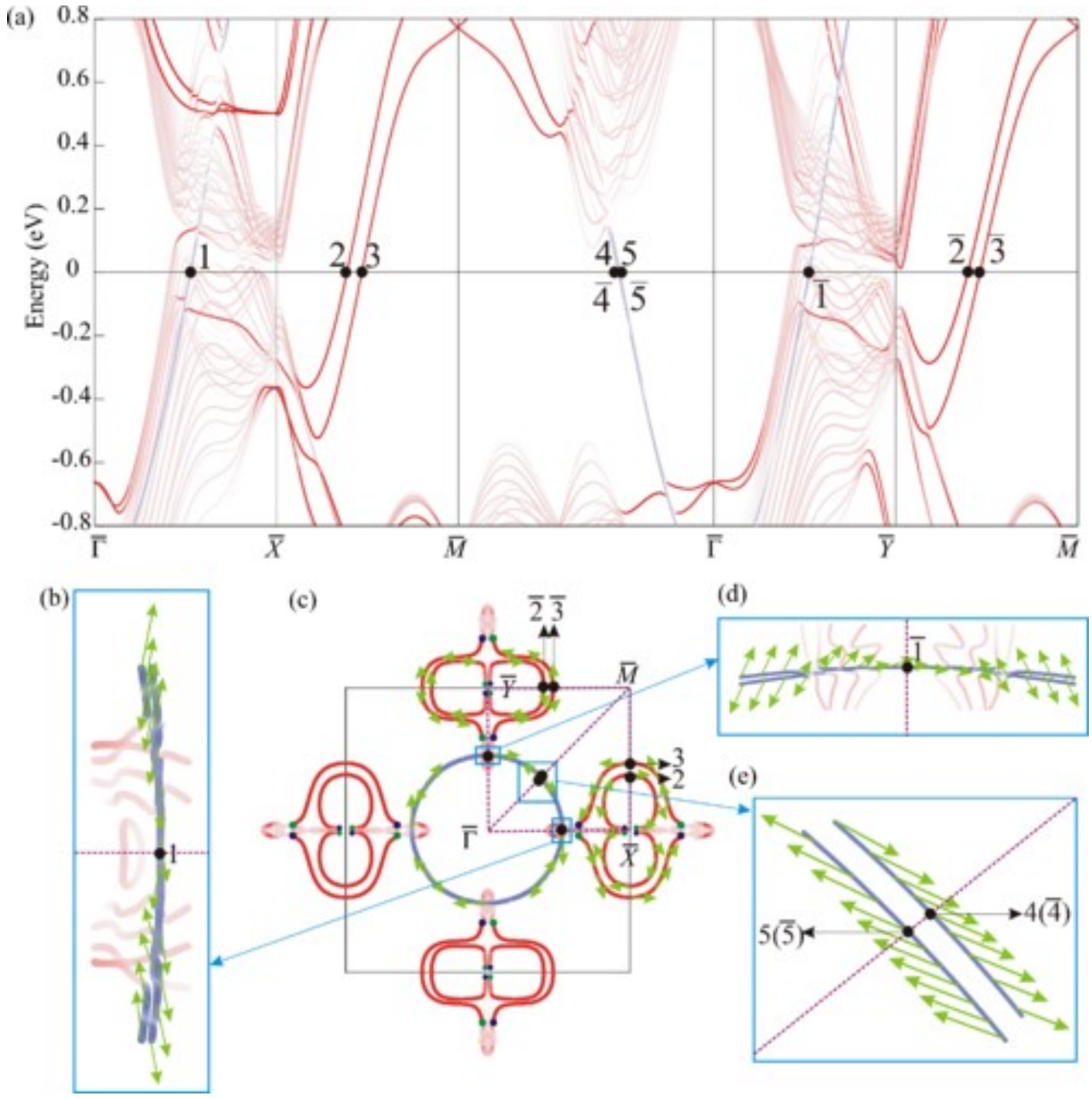

(a)
(b)
(I)
(II)
(III)
(IV)
(V)
(VI)
(VII)
Q
D
A
B

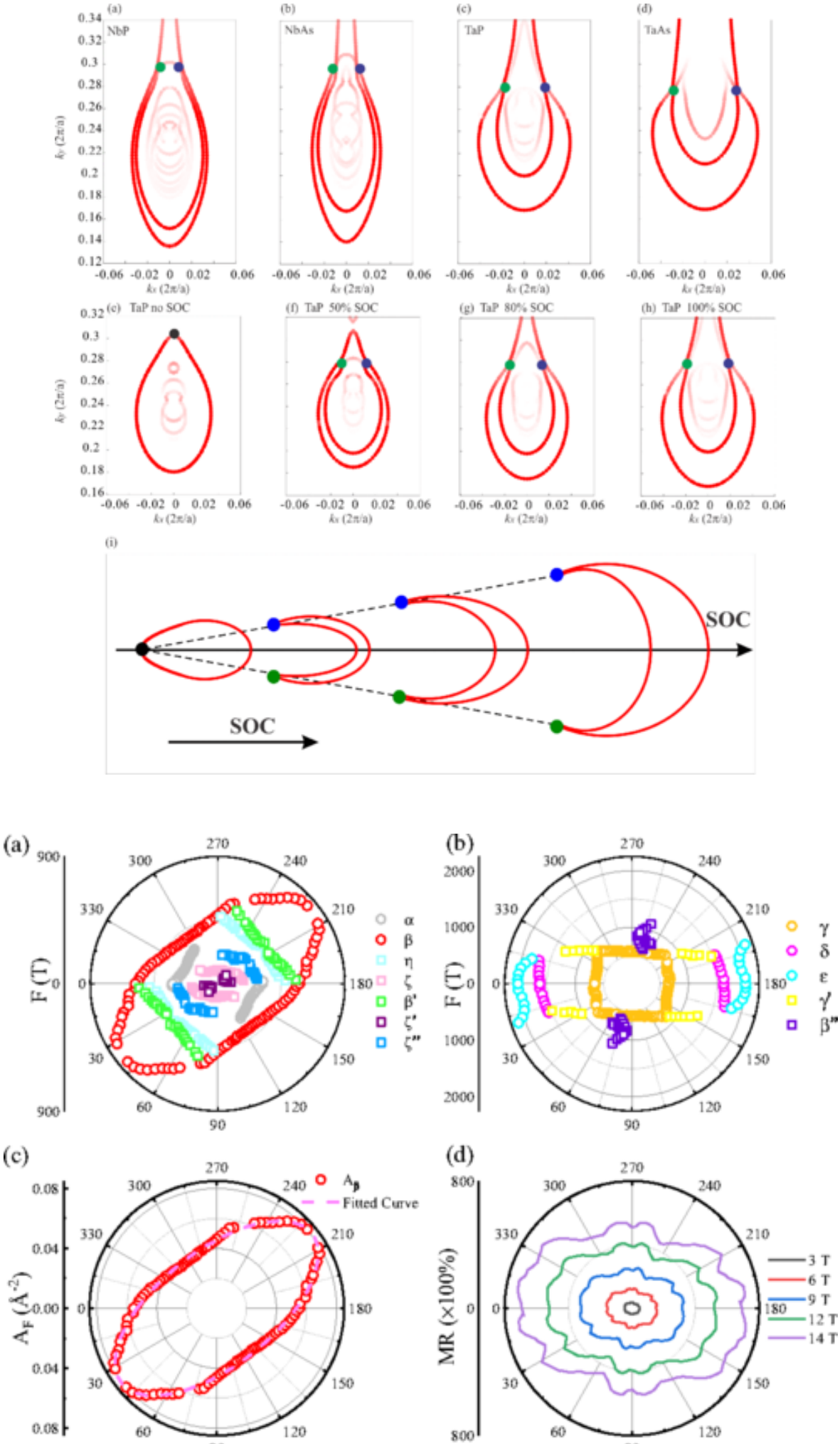

(a)
c
a
b
(b)
Energy (eV)
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
-1.2
(c)
Energy (eV)
$\bar{M}$
$\bar{Y}$
$\bar{\Gamma}$
$\bar{X}$
$\bar{M}$
$\bar{\Gamma}$
(d)
$\bar{Y}$
$\bar{M}$
$\bar{\Gamma}$
$\bar{X}$
(e)
$\bar{Y}$
$\bar{M}$
$\bar{\Gamma}$
$\bar{X}$

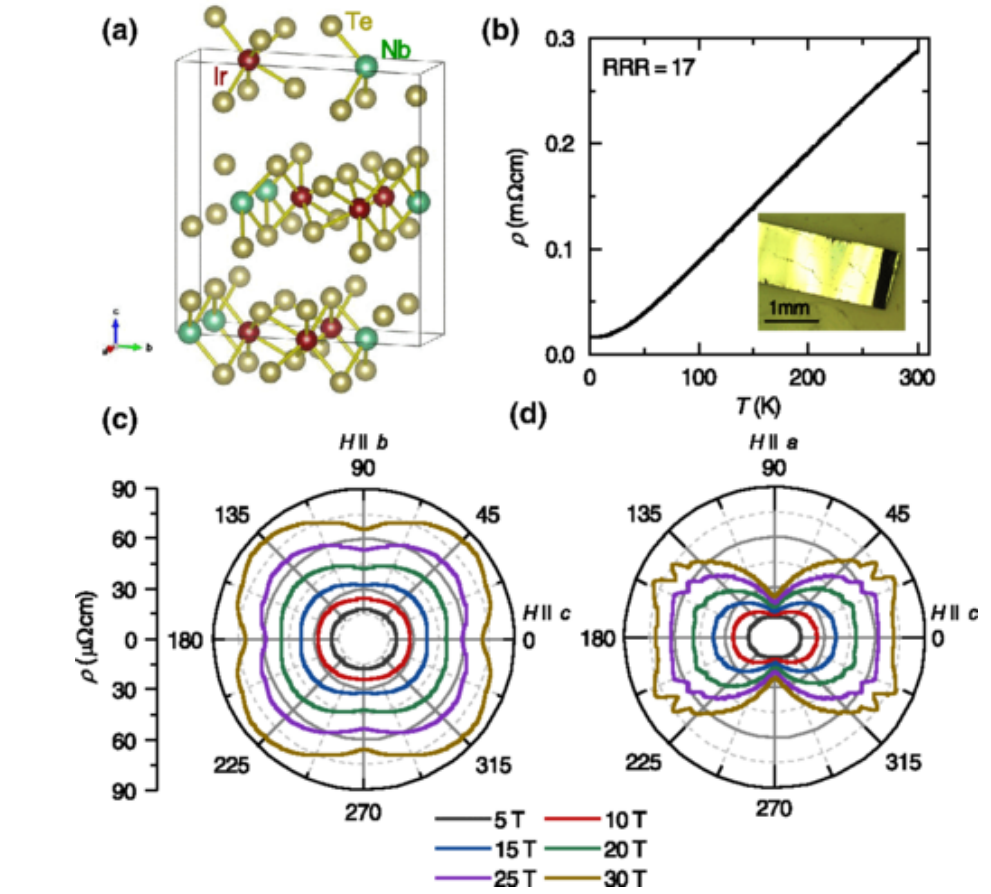

(a)
^{125}Te NMR 290 K H_0||a
Te$_a$
Te$_z$
Te$_d$
Intensity (arb. units)
Shift (ppm)
(b)
290 K
270 K
240 K
210 K
170 K
140 K
110 K
77 K
50 K
30 K
4 K
Te$_a$
Te$_z$
Te$_d$
Intensity (arb. units)
Shift (ppm)
(c)
^{125}Te NMR H_0||a
Shift (ppm)
Te$_d$
Te$_z$
Te$_a$
T (K)
(d)
c (Å)
Te$_z$
Te$_d$
Te$_a$
Band gap at Γ
Chemical Shift (ppm)
Band Gap (eV)
b (Å)
(e)
b = 143.0 nm
c = 135.0 nm
b = 145.3 nm
c = 137.2 nm
Energy (eV)
X Γ Y X,SX
X Γ Y X,SX

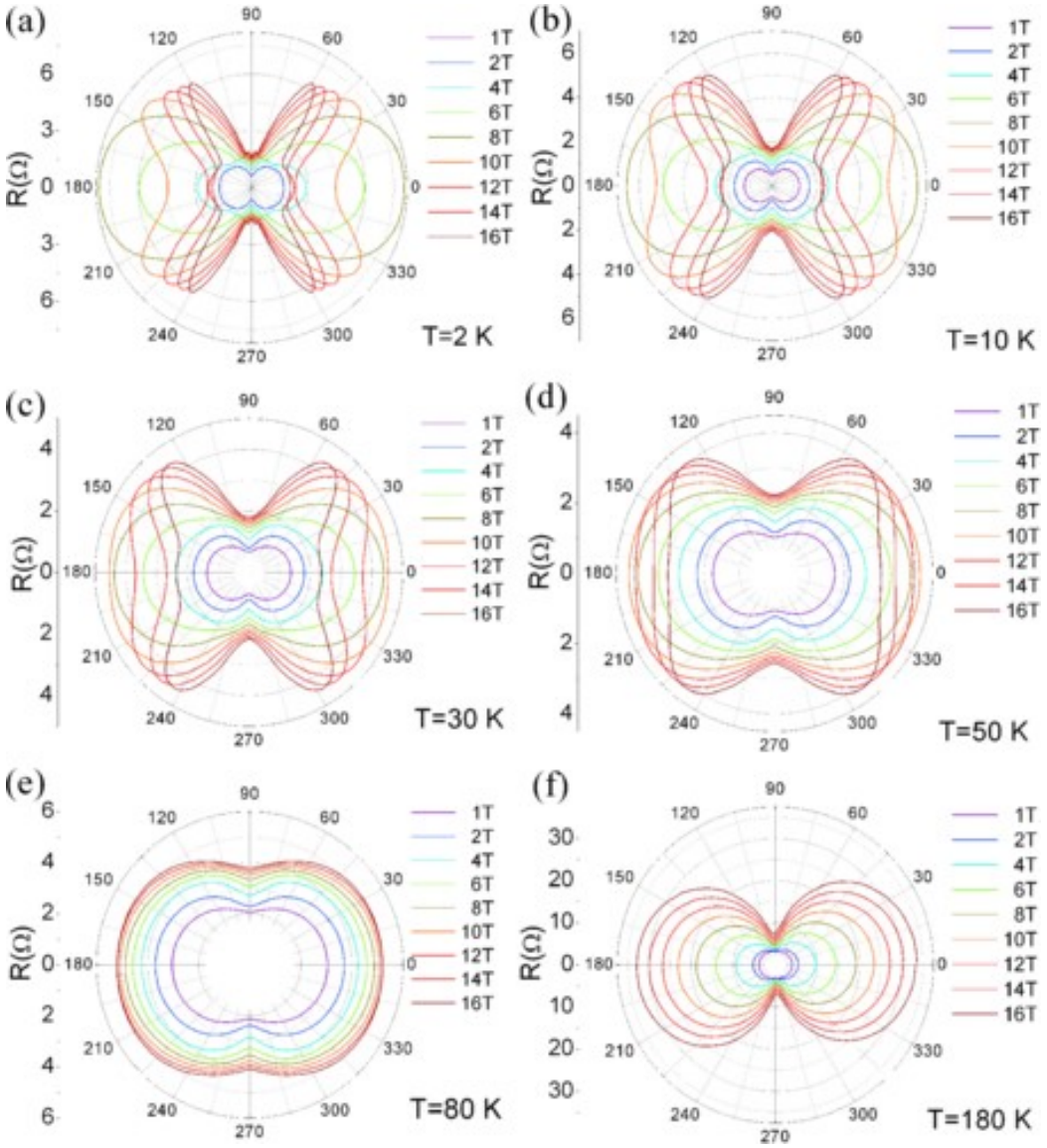

(a)
Energy (eV)
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
1 2 3 4 5
$\bar{1}$ $\bar{2}$ $\bar{3}$ $\bar{4}$ $\bar{5}$
$\bar{\Gamma}$ $\bar{X}$ $\bar{M}$ $\bar{\Gamma}$ $\bar{Y}$ $\bar{M}$
(b)
$\bar{M}$
5 4
1 2
W2
3
W1
$\bar{\Gamma}$
$\bar{X}$
(c)
W1
$\bar{4}$ $\bar{5}$
$\bar{M}$
$\bar{3}$
$\bar{Y}$
W2
$\bar{2}$ $\bar{1}$
$\bar{\Gamma}$
(d)
$\bar{Y}$
W1
$\bar{4}$ $\bar{5}$
$\bar{M}$
$\bar{3}$
W2
5 4
$\bar{2}$ $\bar{1}$
W2
1 2
3
W1
$\bar{\Gamma}$
$\bar{X}$
(a)
(b)
(f)
(g)
k_y
$\bar{M}$
$\bar{\Gamma}$
$\bar{X}$
k_x
(c)
Fermi arcs
(h)
k_y
$\bar{M}$
$\bar{Y}$
k_x
Fermi arcs
(d)
(e)
(i)
(j)
$\bar{\Gamma}$

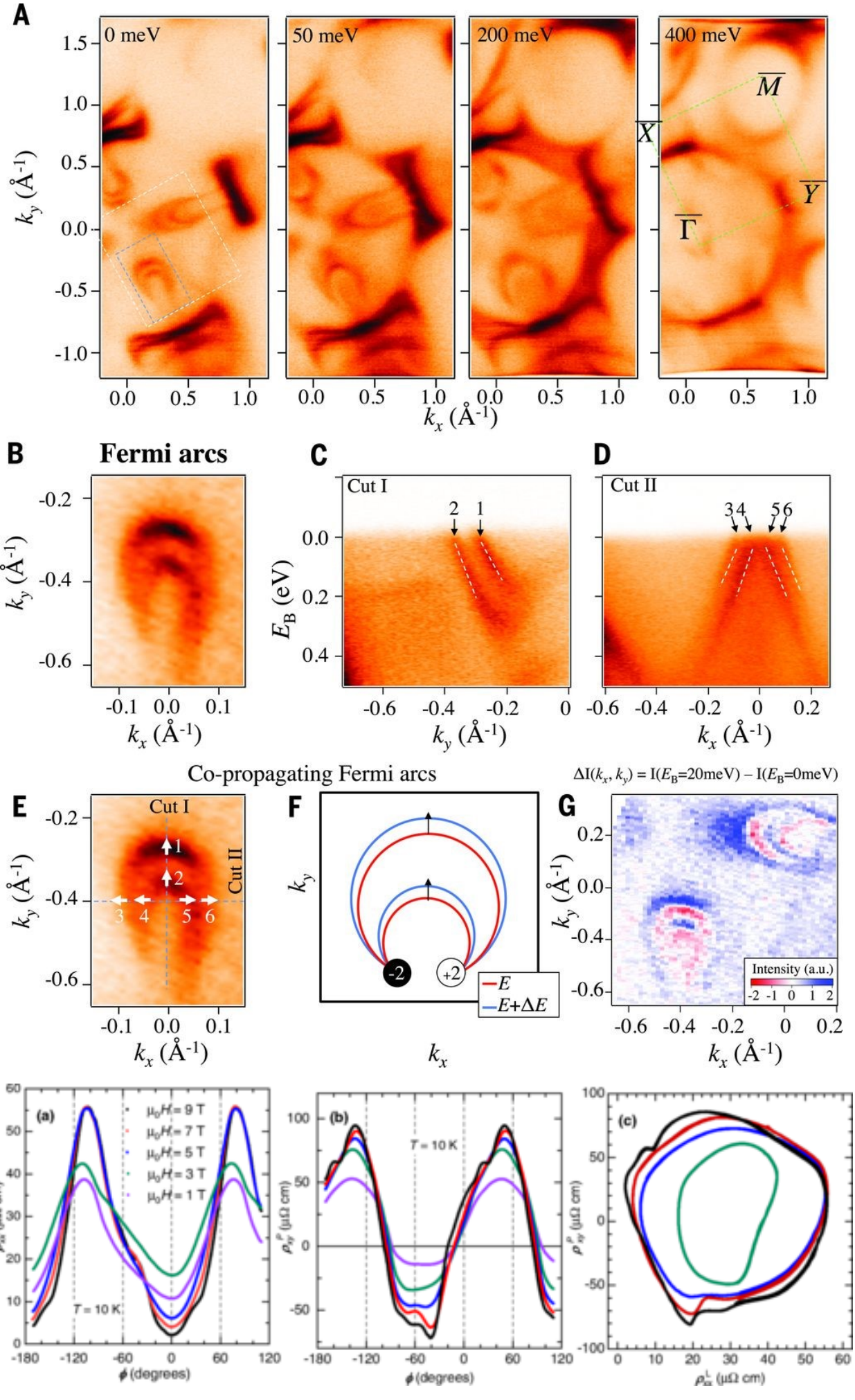

(a) Ef-40 (meV)
(b) Ef
(c) Ef+40 (meV)
(d) Ef+70 (meV)
0.32
0.28
0.24
0.2
0.16
0.12
ky (2π/a)
-0.05 0 0.05
kx (2π/a)
(e) Ef-40 (meV)
(f) Ef
0.55
0.5
0.45
-0.06 -0.04 -0.02 0 0.02 0.04 0.06
(g) Ef+35 (meV)
(h) Ef+50 (meV)

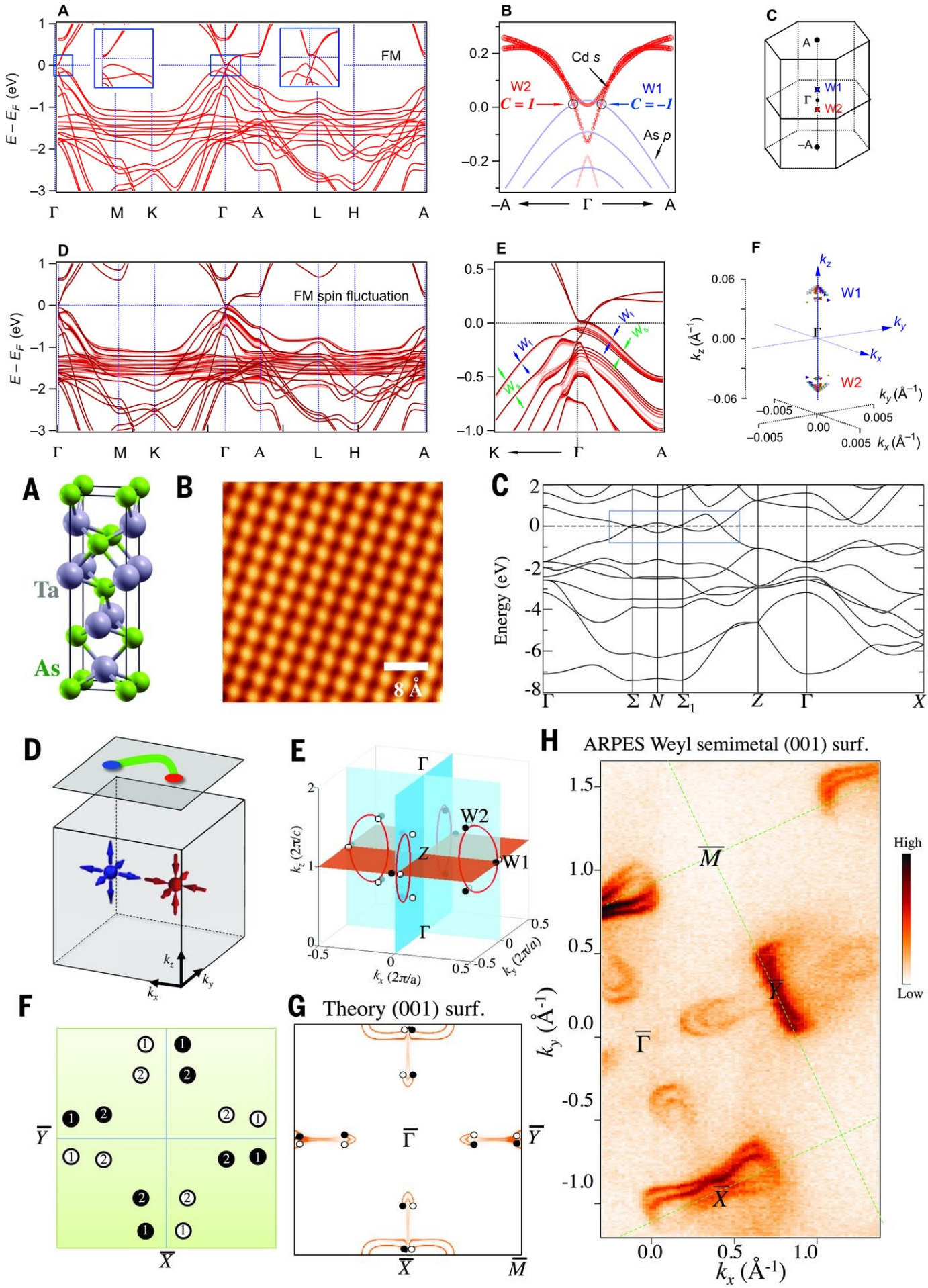

(a)
Energy (eV)
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
1
2 3
4 5
4̄ 5̄
1̄
2̄ 3̄
Γ̄
X̄
M̄
Γ̄
Ȳ
M̄
(b)
1
(c)
2̄ 3̄
Ȳ
M̄
3
2
Γ̄
X̄
(d)
1̄
(e)
4(4̄)
5(5̄)

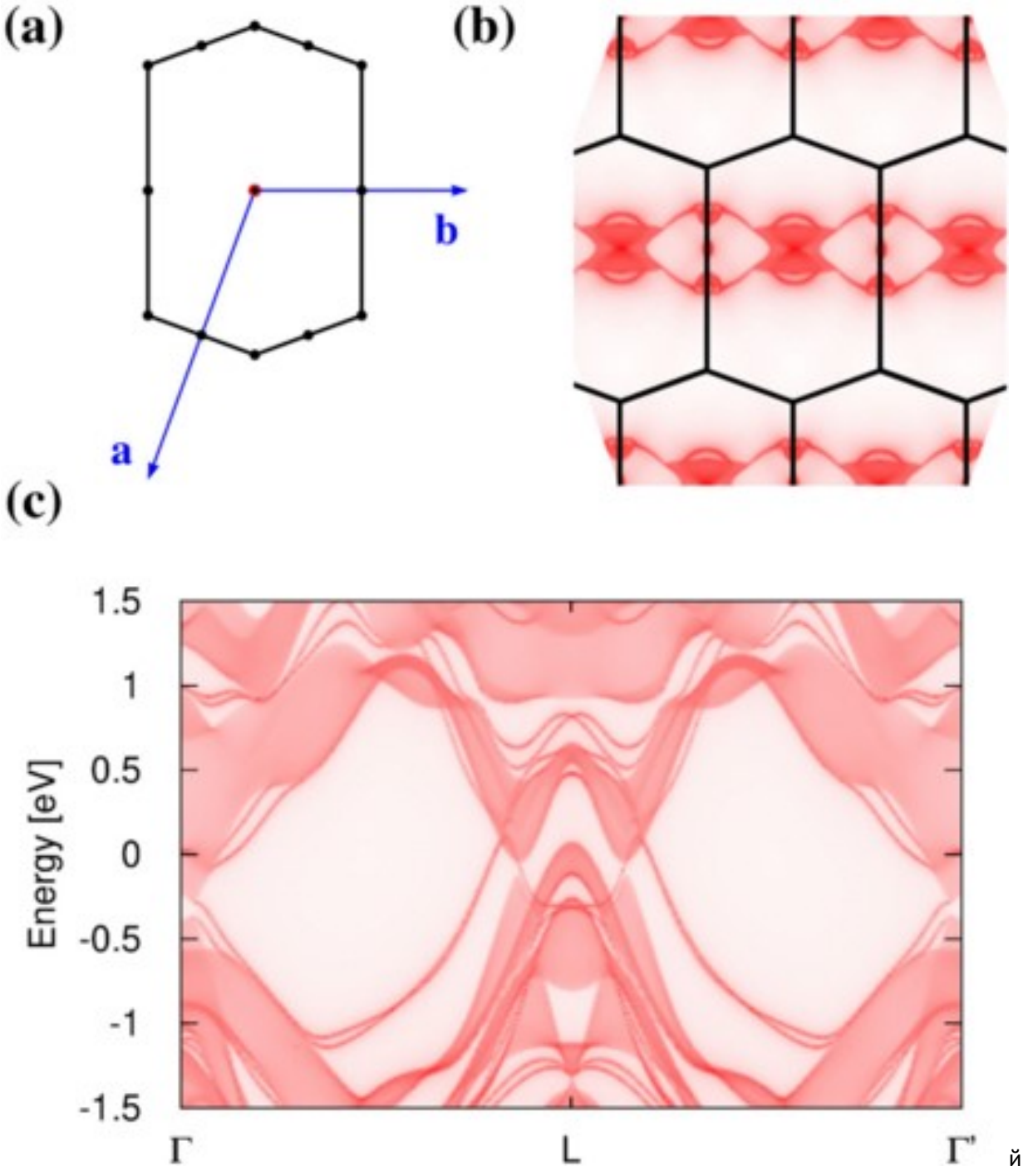

(a) NbP
(b) NbAs
(c) TaP
(d) TaAs
(e) TaP no SOC
(f) TaP 50% SOC
(g) TaP 80% SOC
(h) TaP 100% SOC
(i)
SOC
SOC
(a)
F (T)
α
β
η
ζ
β'
ζ'
ζ''
(b)
F (T)
γ
δ
ε
γ'
β''
(c)
A_F ($Å^{-2}$)
A_β
Fitted Curve
(d)
MR (×100%)
3 T
6 T
9 T
12 T
14 T


(a)
Te
Nb
Ir
(b)
RRR = 17
ρ (mΩcm)
T (K)
1mm
(c)
H ∥ b
H ∥ c
ρ (μΩcm)
(d)
H ∥ a
H ∥ c
5 T
10 T
15 T
20 T
25 T
30 T

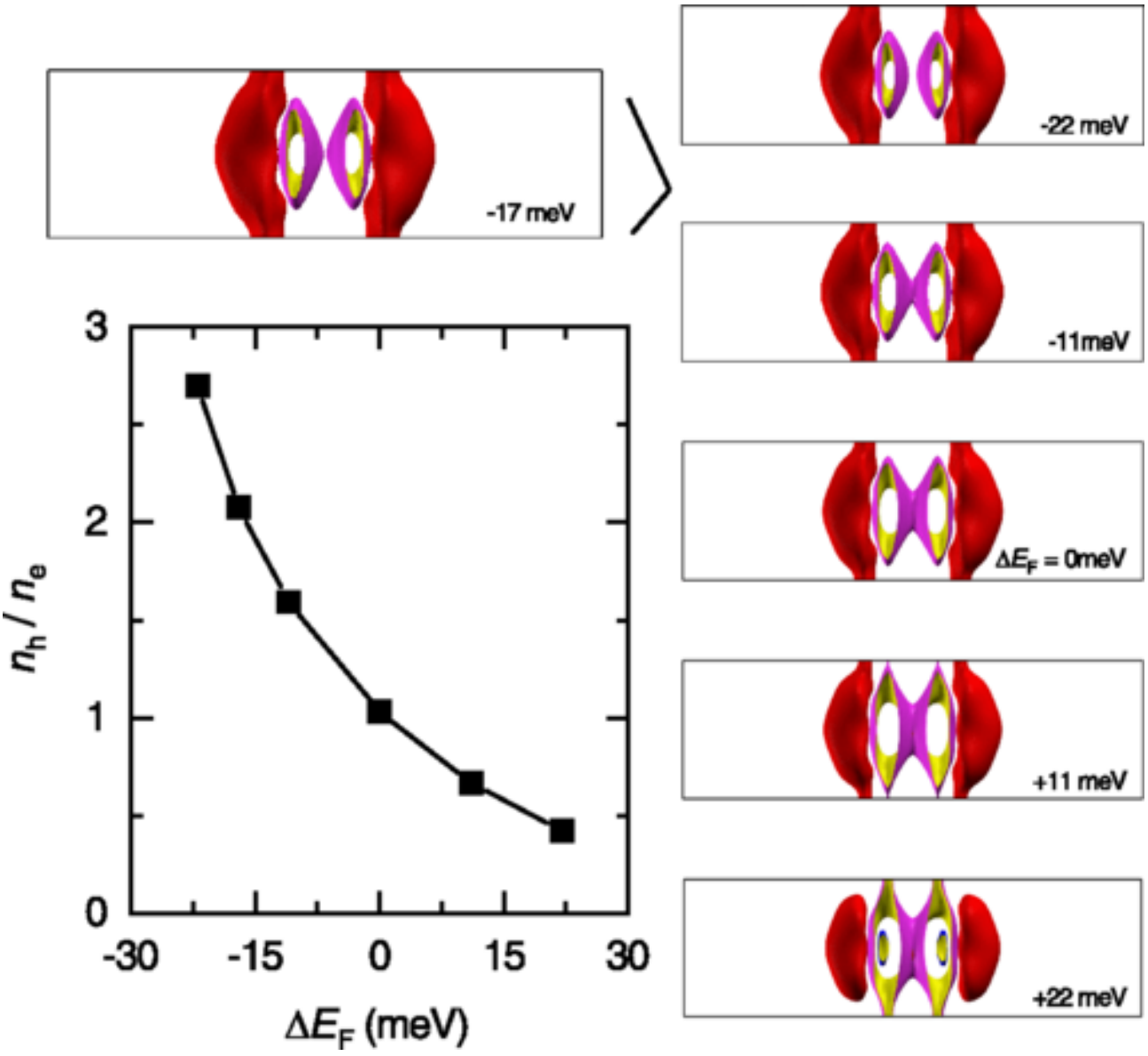

(a)
T=2 K
(b)
T=10 K
(c)
T=30 K
(d)
T=50 K
(e)
T=80 K
(f)
T=180 K
R(Ω)
1T
2T
4T
6T
8T
10T
12T
14T
16T

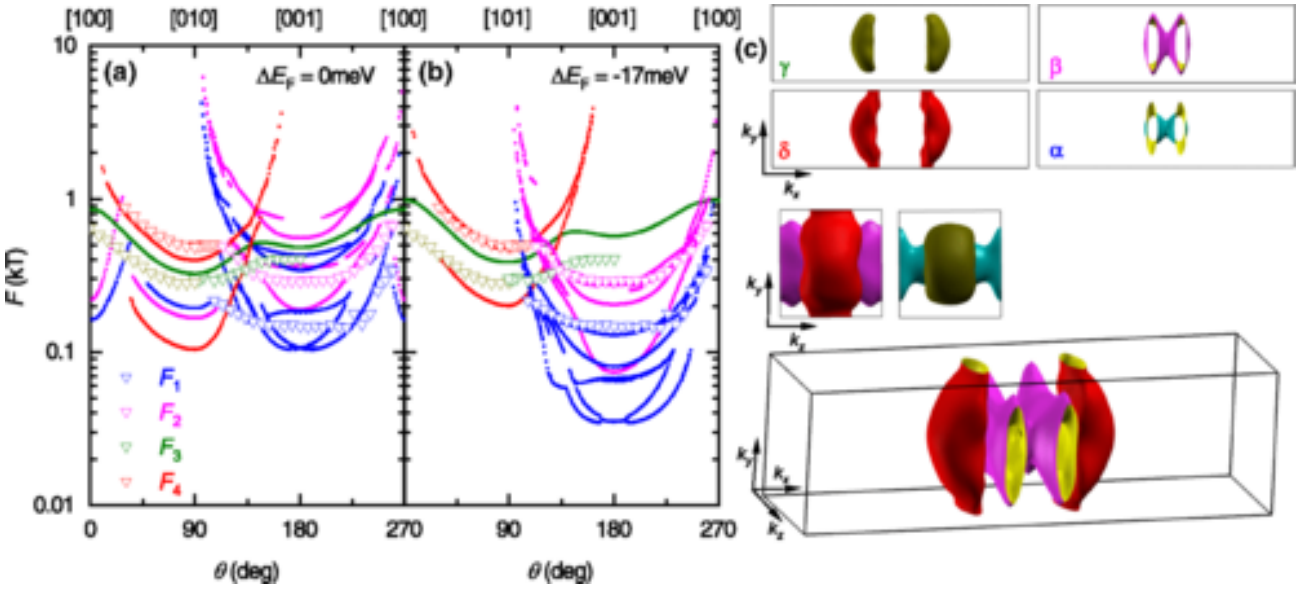

A
0 meV
50 meV
200 meV
400 meV
k_y (Å^{-1})
k_x (Å^{-1})
$\overline{M}$
$\overline{X}$
$\overline{Y}$
$\overline{\Gamma}$
B
Fermi arcs
C
Cut I
D
Cut II
E_B (eV)
Co-propagating Fermi arcs
$\Delta I(k_x, k_y) = I(E_B=20meV) - I(E_B=0meV)$
E
F
G
Intensity (a.u.)
E
$E+\Delta E$
(a)
(b)
(c)
$\mu_0 H$ = 9 T
$\mu_0 H$ = 7 T
$\mu_0 H$ = 5 T
$\mu_0 H$ = 3 T
$\mu_0 H$ = 1 T
T = 10 K
ϕ (degrees)

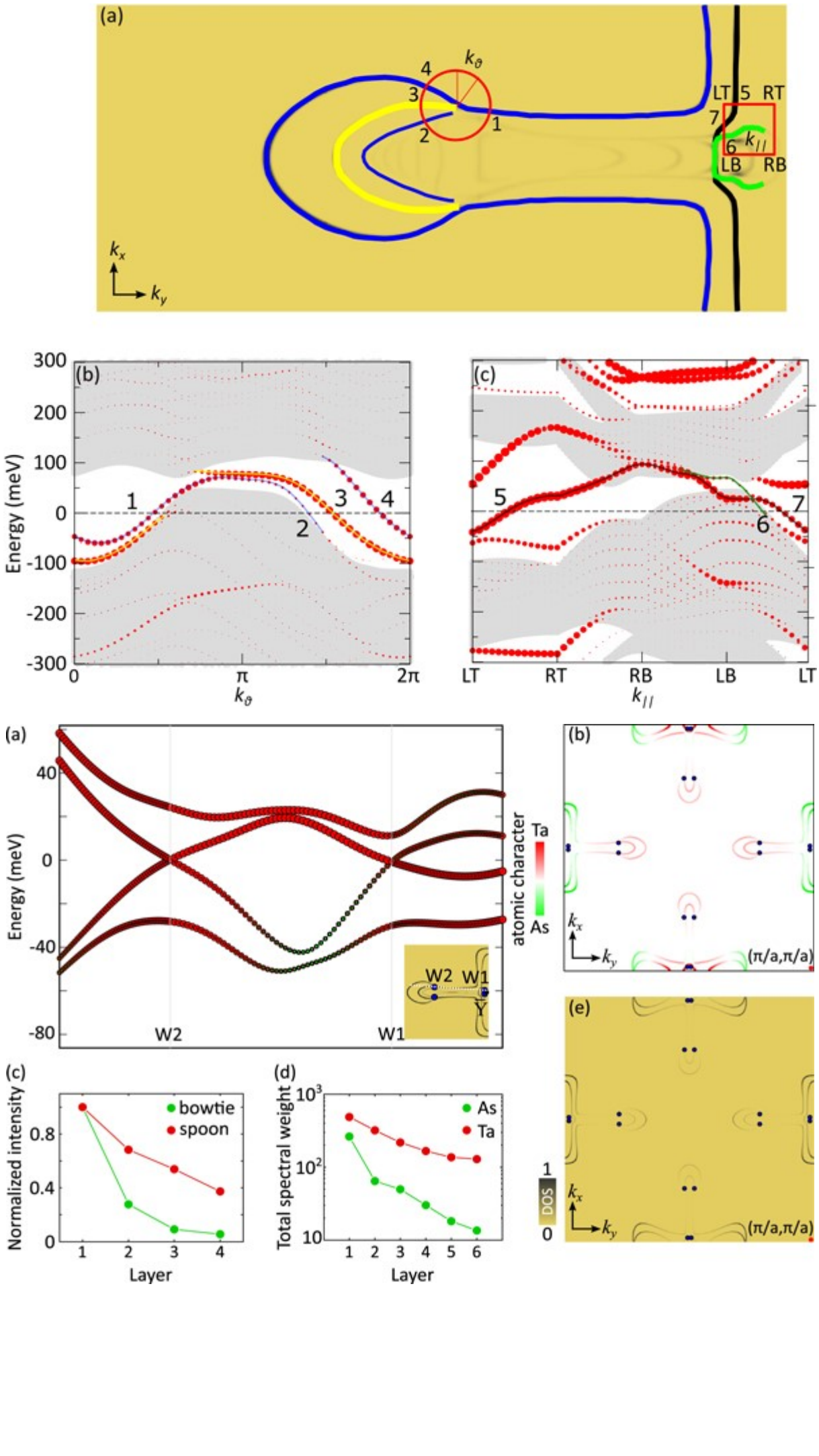

A
B
C
D
E
F
FM
FM spin fluctuation
Cd s
As p
W1
W2
C = 1
C = −1
Γ M K Γ A L H A
K Γ A
E − E_F (eV)
k_z
k_y
k_x
k_z (Å^−1)
k_y (Å^−1)
k_x (Å^−1)
A
B
C
Ta
As
8 Å
Energy (eV)
Γ Σ N Σ_1 Z Γ X
D
E
F
G
H
k_z
k_y
k_x
k_z (2π/c)
k_x (2π/a)
k_y (2π/a)
W2
W1
Z
Γ
Y
X
M
Theory (001) surf.
ARPES Weyl semimetal (001) surf.
High
Low
k_y (Å^-1)
k_x (Å^-1)

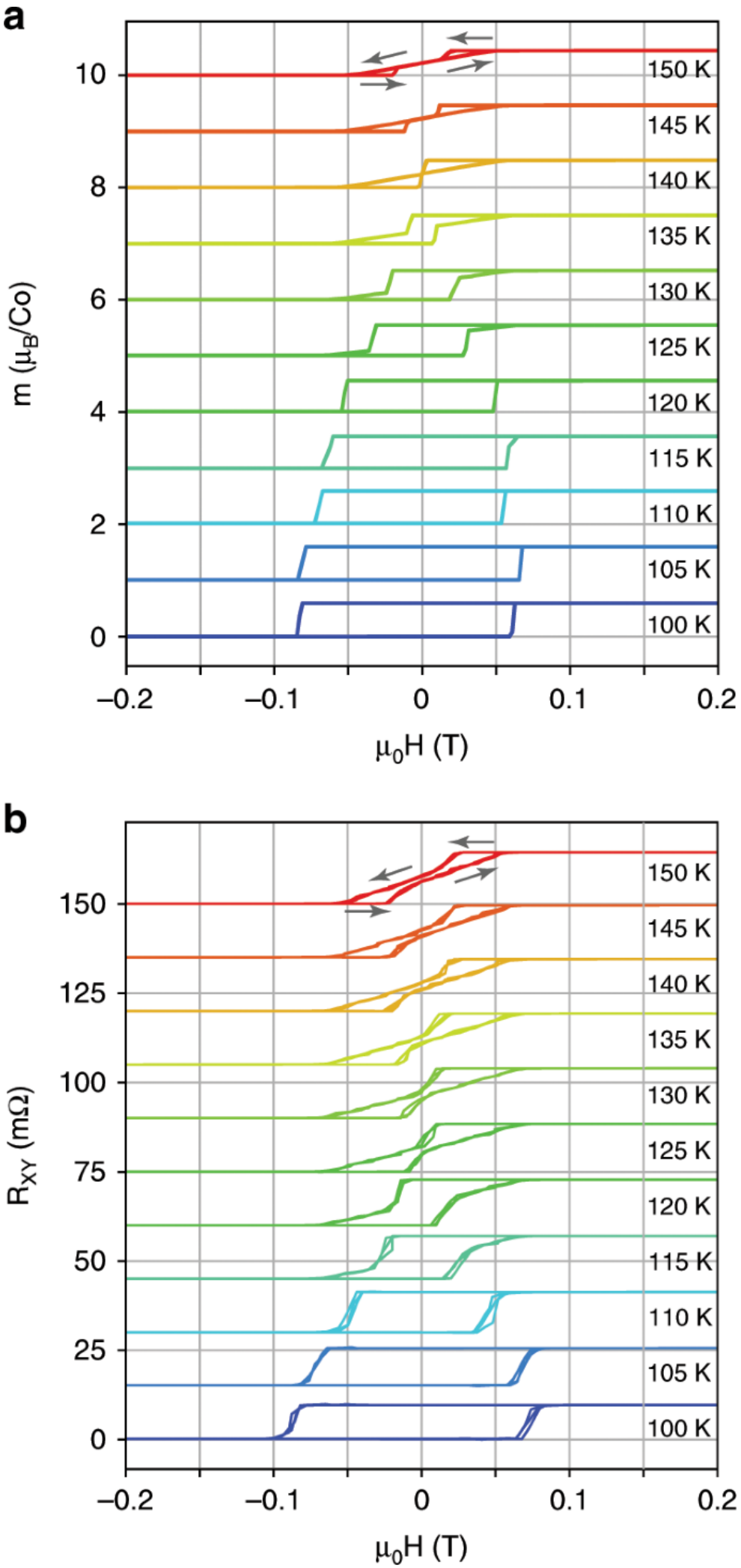


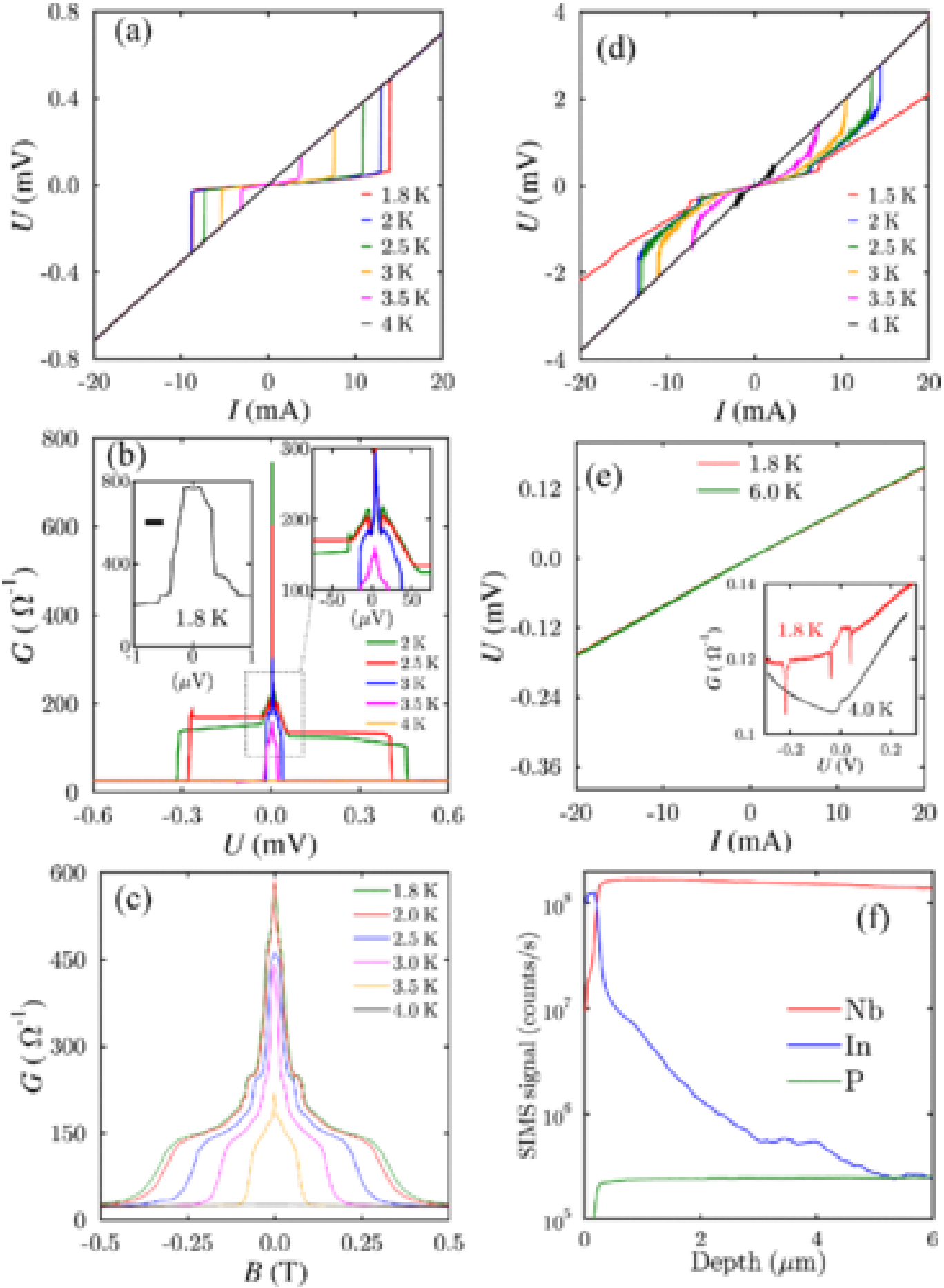
й

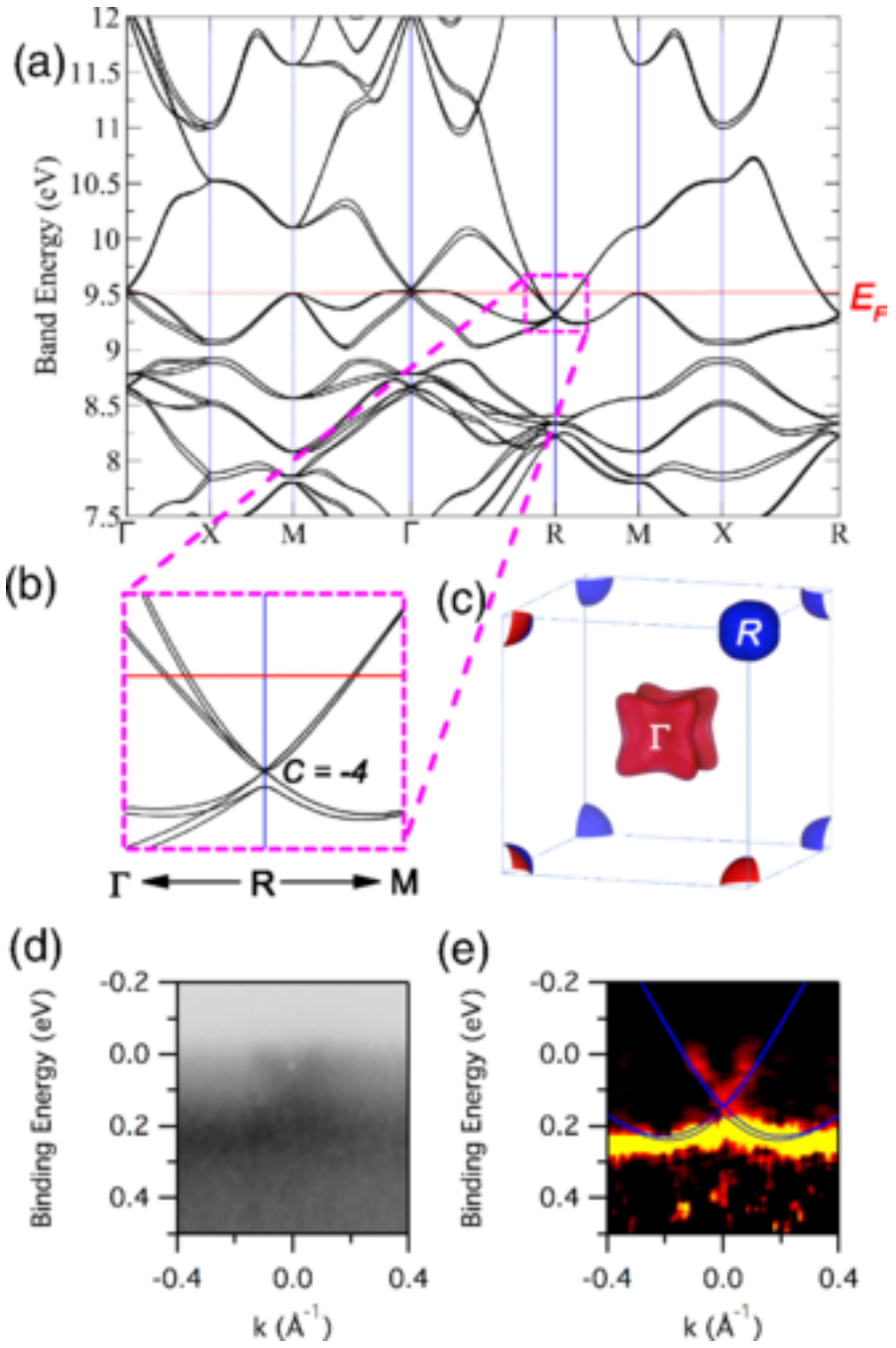

-17 meV
-22 meV
-11meV
ΔE_F = 0meV
+11 meV
+22 meV
n_h / n_e
ΔE_F (meV)

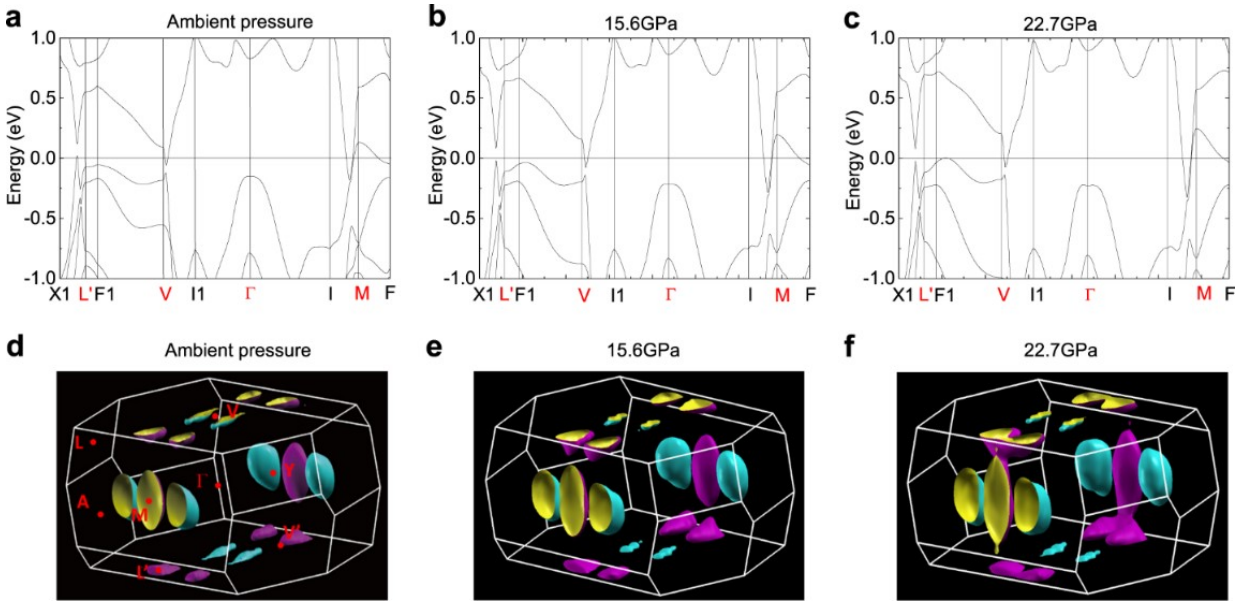

[100]
[010]
[001]
[100]
[101]
[001]
[100]
(a)
ΔE_F = 0meV
(b)
ΔE_F = -17meV
(c)
γ
β
δ
α
F (kT)
F1
F2
F3
F4
θ (deg)
θ (deg)

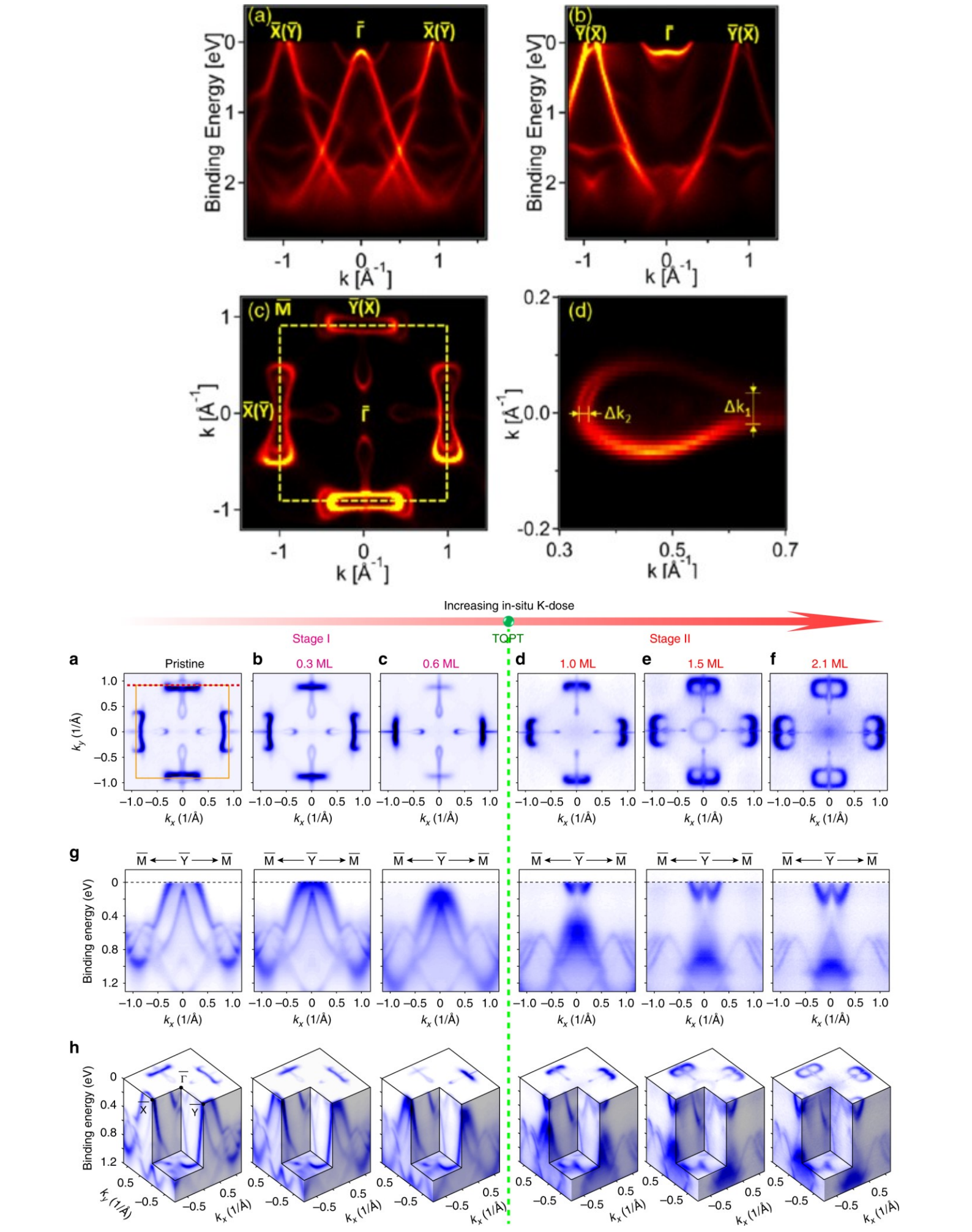

(a)
k_θ
4
3
2
1
LT
5
RT
7
6
$k_{//}$
LB
RB
k_x
k_y
(b)
Energy (meV)
300
200
100
0
-100
-200
-300
1
2
3
4
0
π
2π
k_θ
(c)
5
6
7
LT
RT
RB
LB
LT
$k_{//}$
(a)
Energy (meV)
40
0
-40
-80
W2
W1
W2
W1
Y
atomic character
Ta
As
(b)
k_x
k_y
(π/a,π/a)
(c)
Normalized intensity
0.8
0.4
0
bowtie
spoon
1
2
3
4
Layer
(d)
Total spectral weight
10^3
10^2
10
As
Ta
1
2
3
4
5
6
Layer
(e)
1
DOS
0
k_x
k_y
(π/a,π/a)

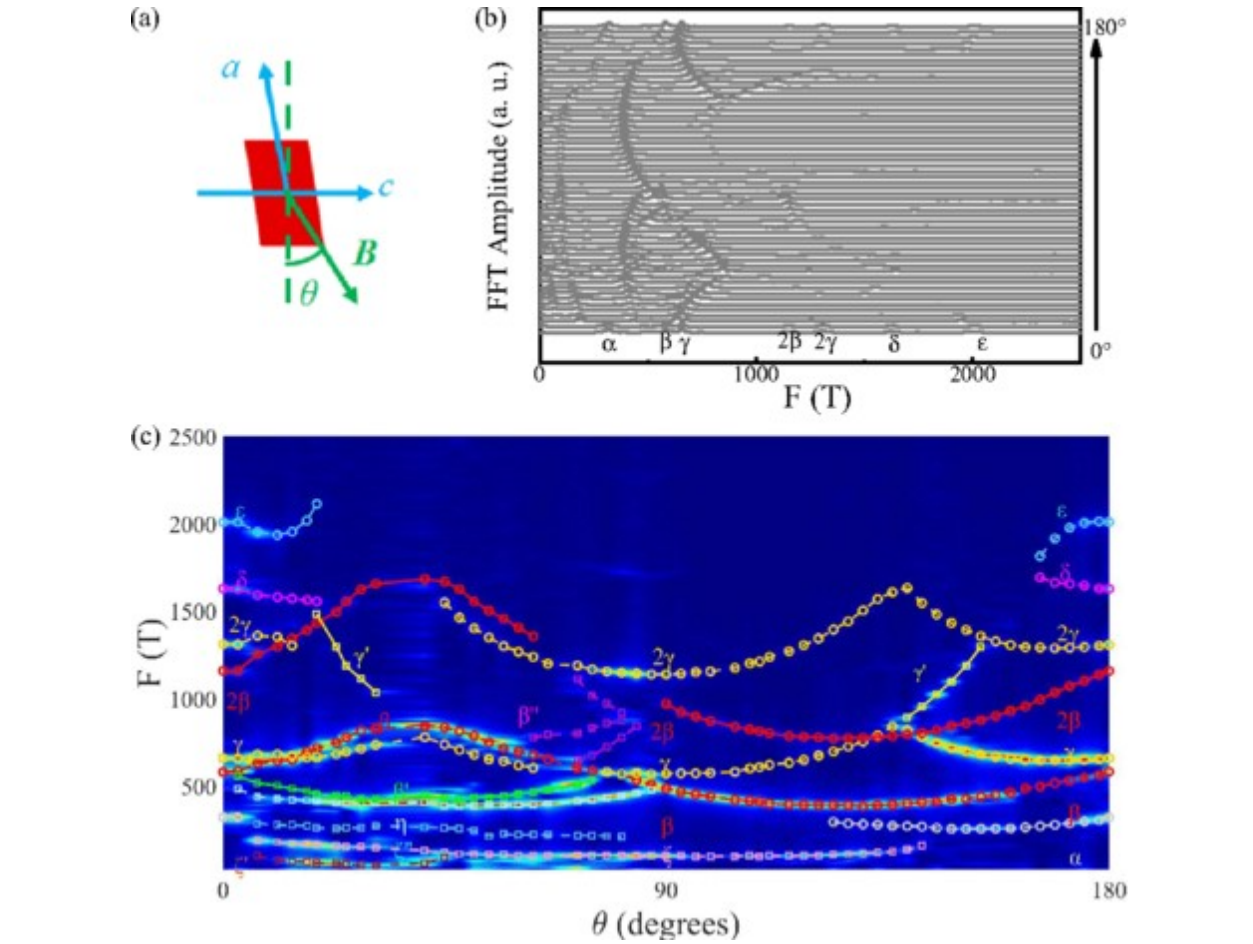

a
m (μB/Co)
10
8
6
4
2
0
150 K
145 K
140 K
135 K
130 K
125 K
120 K
115 K
110 K
105 K
100 K
–0.2
–0.1
0
0.1
0.2
μ0H (T)
b
RXY (mΩ)
150
125
100
75
50
25
0
150 K
145 K
140 K
135 K
130 K
125 K
120 K
115 K
110 K
105 K
100 K
–0.2
–0.1
0
0.1
0.2
μ0H (T)

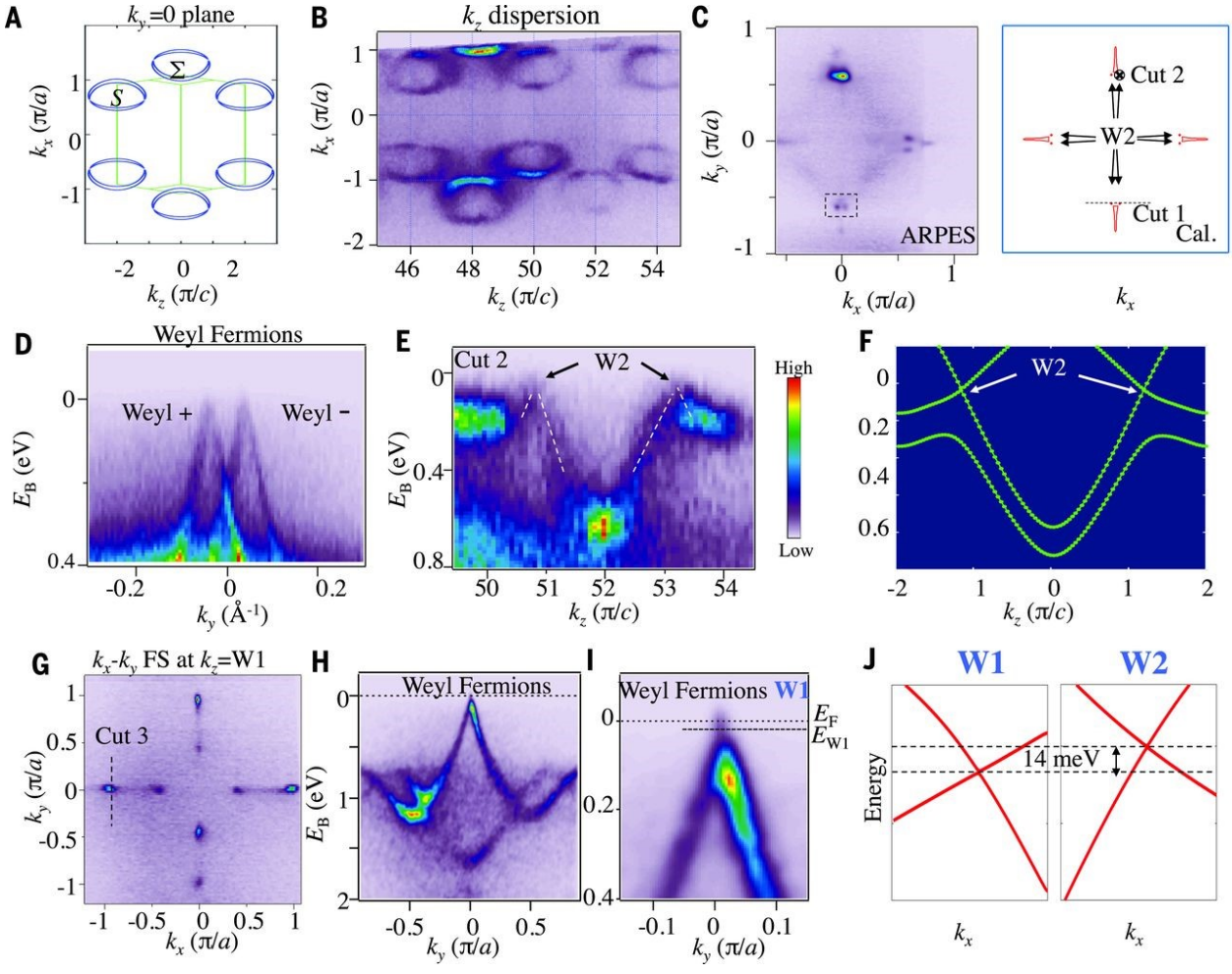

(a)
U (mV)
I (mA)
1.8 K
2 K
2.5 K
3 K
3.5 K
4 K
(d)
U (mV)
I (mA)
1.5 K
2 K
2.5 K
3 K
3.5 K
4 K
(b)
G (Ω⁻¹)
U (mV)
1.8 K
(μV)
2 K
2.5 K
3 K
3.5 K
4 K
(e)
U (mV)
I (mA)
1.8 K
6.0 K
1.8 K
4.0 K
G (Ω⁻¹)
U (V)
(c)
G (Ω⁻¹)
B (T)
1.8 K
2.0 K
2.5 K
3.0 K
3.5 K
4.0 K
(f)
SIMS signal (counts/s)
Depth (μm)
Nb
In
P

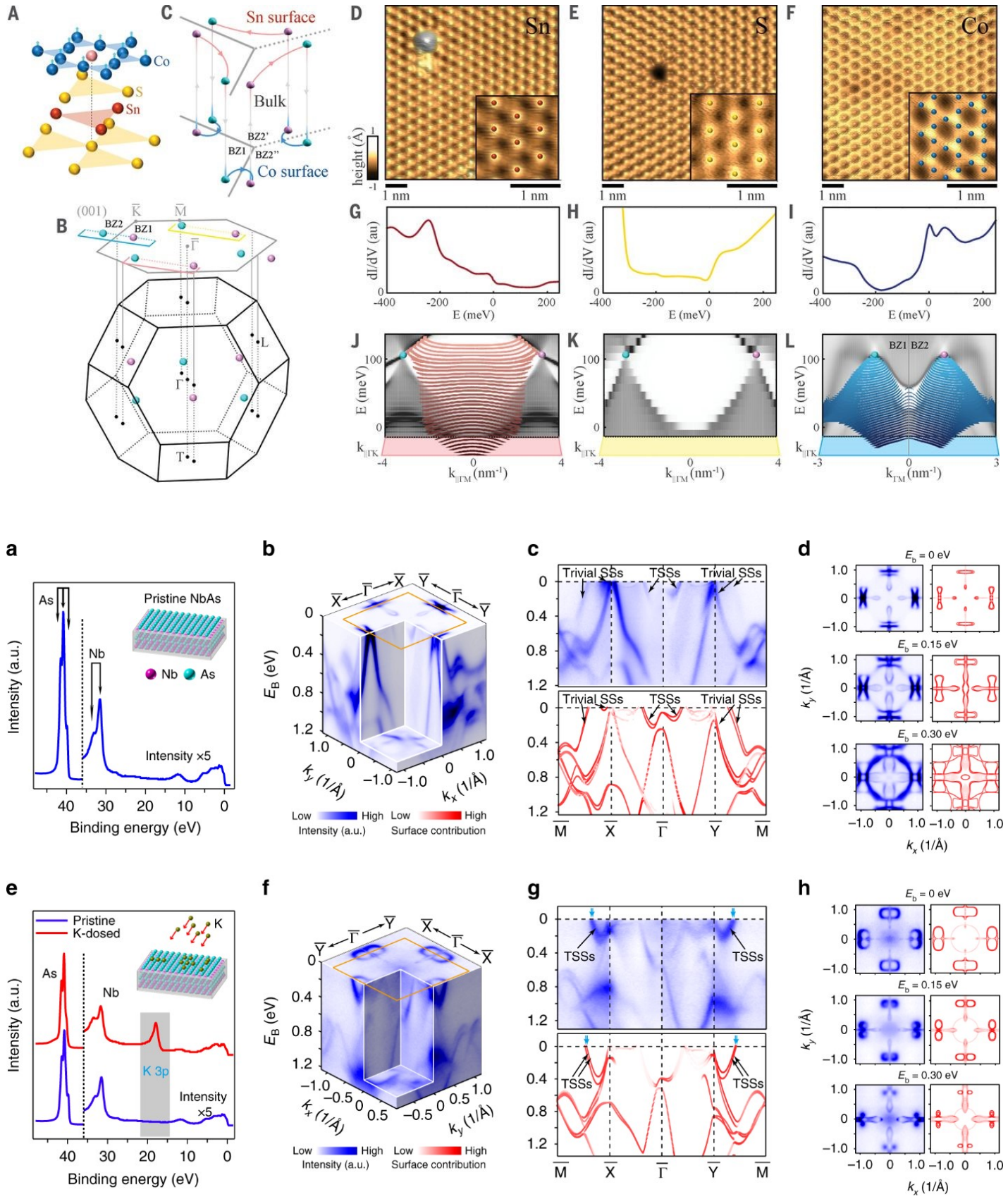

(a)
Band Energy (eV)
12
11.5
11
10.5
10
9.5
9
8.5
8
7.5
Γ X M Γ R M X R
E_F
(b)
C = -4
Γ R M
(c)
R
Γ
(d)
Binding Energy (eV)
-0.2
0.0
0.2
0.4
-0.4 0.0 0.4
k (Å^{-1})
(e)
Binding Energy (eV)
-0.2
0.0
0.2
0.4
-0.4 0.0 0.4
k (Å^{-1})

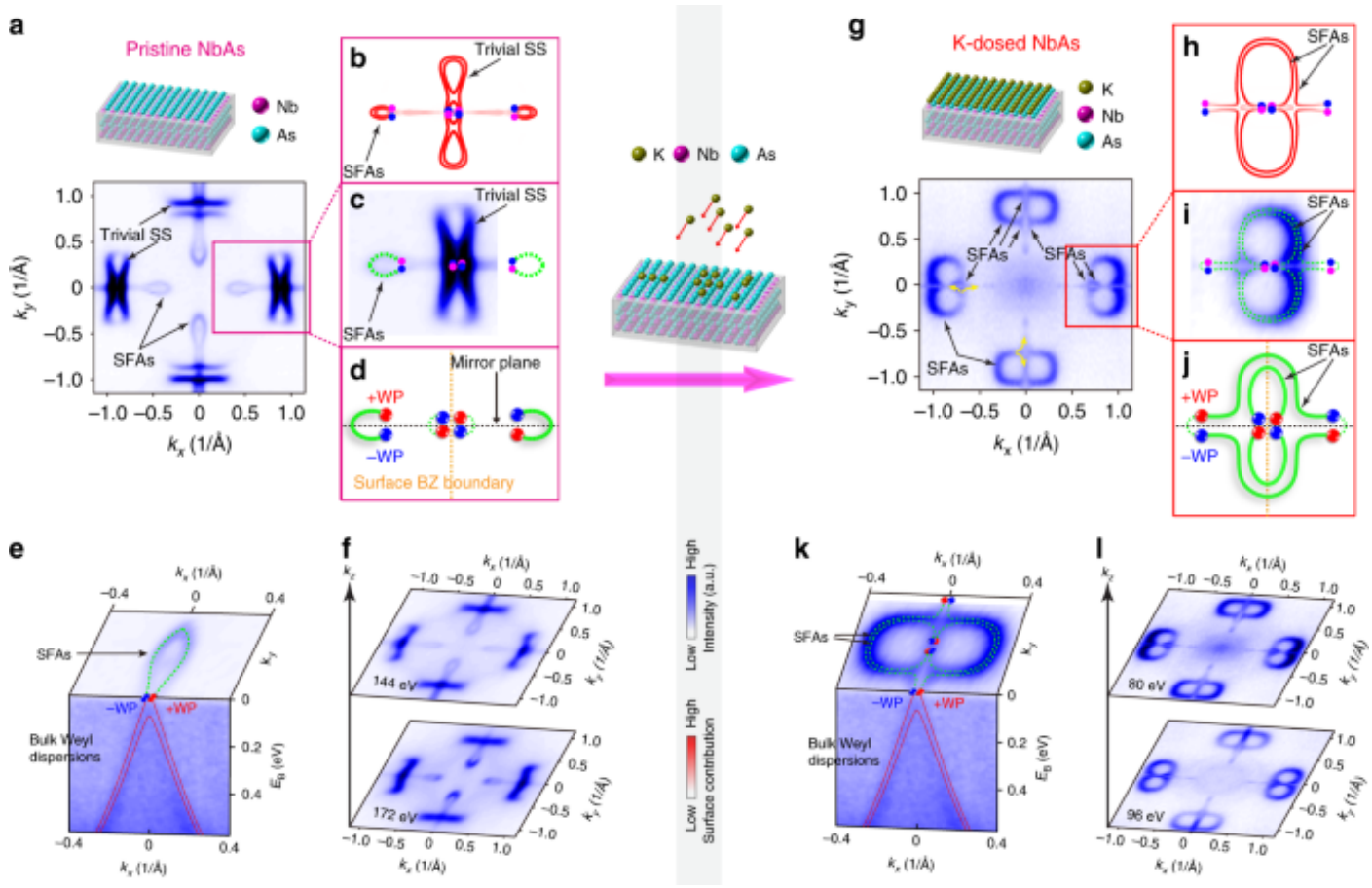

a
Ambient pressure
b
15.6GPa
c
22.7GPa
Energy (eV)
1.0
0.5
0.0
-0.5
-1.0
X1 L'F1 V I1 Γ I M F
d
Ambient pressure
e
15.6GPa
f
22.7GPa

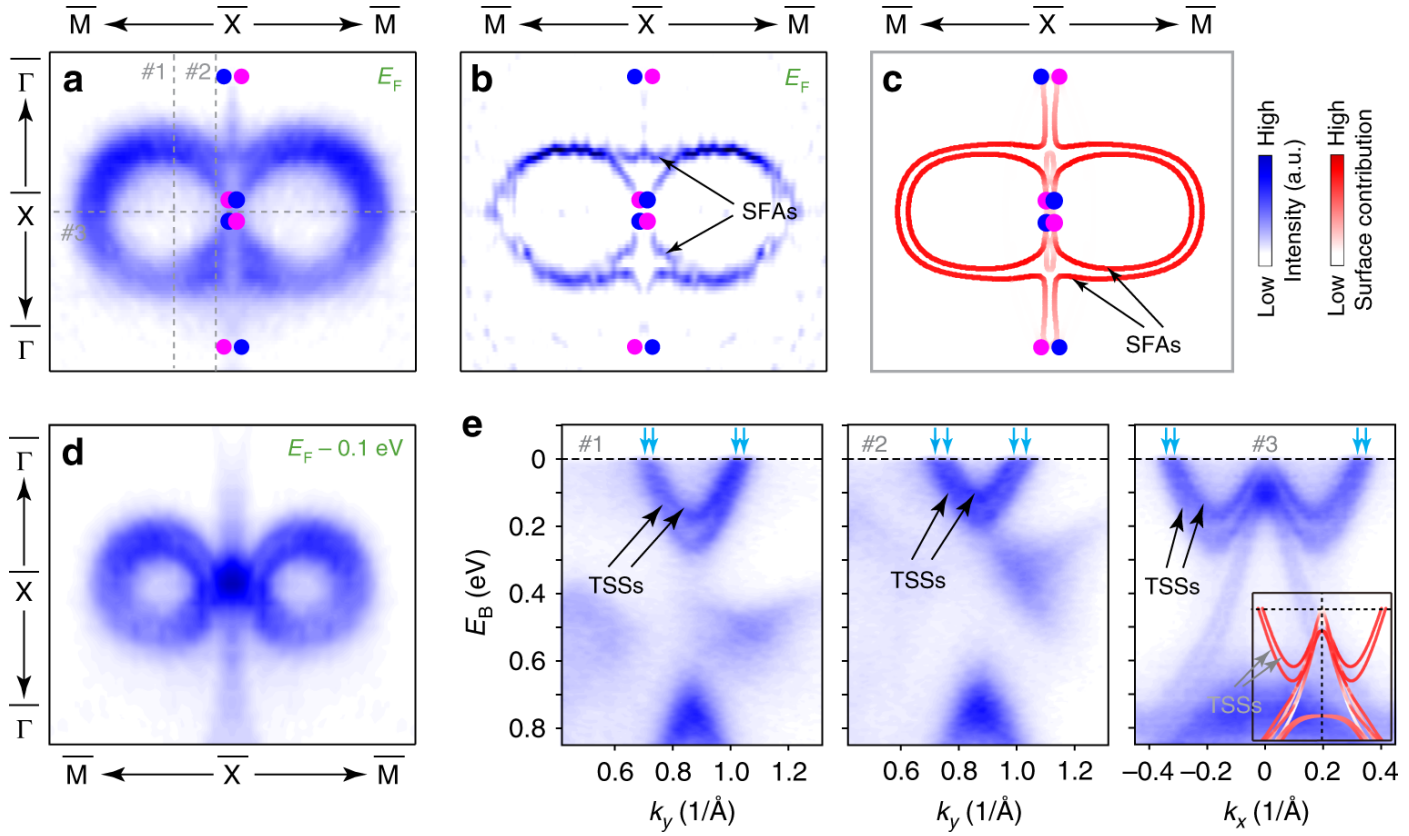

(a)
X̄(Ȳ)
Γ̄
X̄(Ȳ)
Binding Energy [eV]
k [Å^{-1}]
(b)
Ȳ(X̄)
Γ̄
Ȳ(X̄)
(c) M̄
Ȳ(X̄)
X̄(Ȳ)
Γ̄
(d)
Δk$_2$
Δk$_1$
Increasing in-situ K-dose
Stage I
TQPT
Stage II
a Pristine
b 0.3 ML
c 0.6 ML
d 1.0 ML
e 1.5 ML
f 2.1 ML
k$_y$ (1/Å)
k$_x$ (1/Å)
g
M̄ ← Ȳ → M̄
Binding energy (eV)
h
Γ̄
X̄
Ȳ

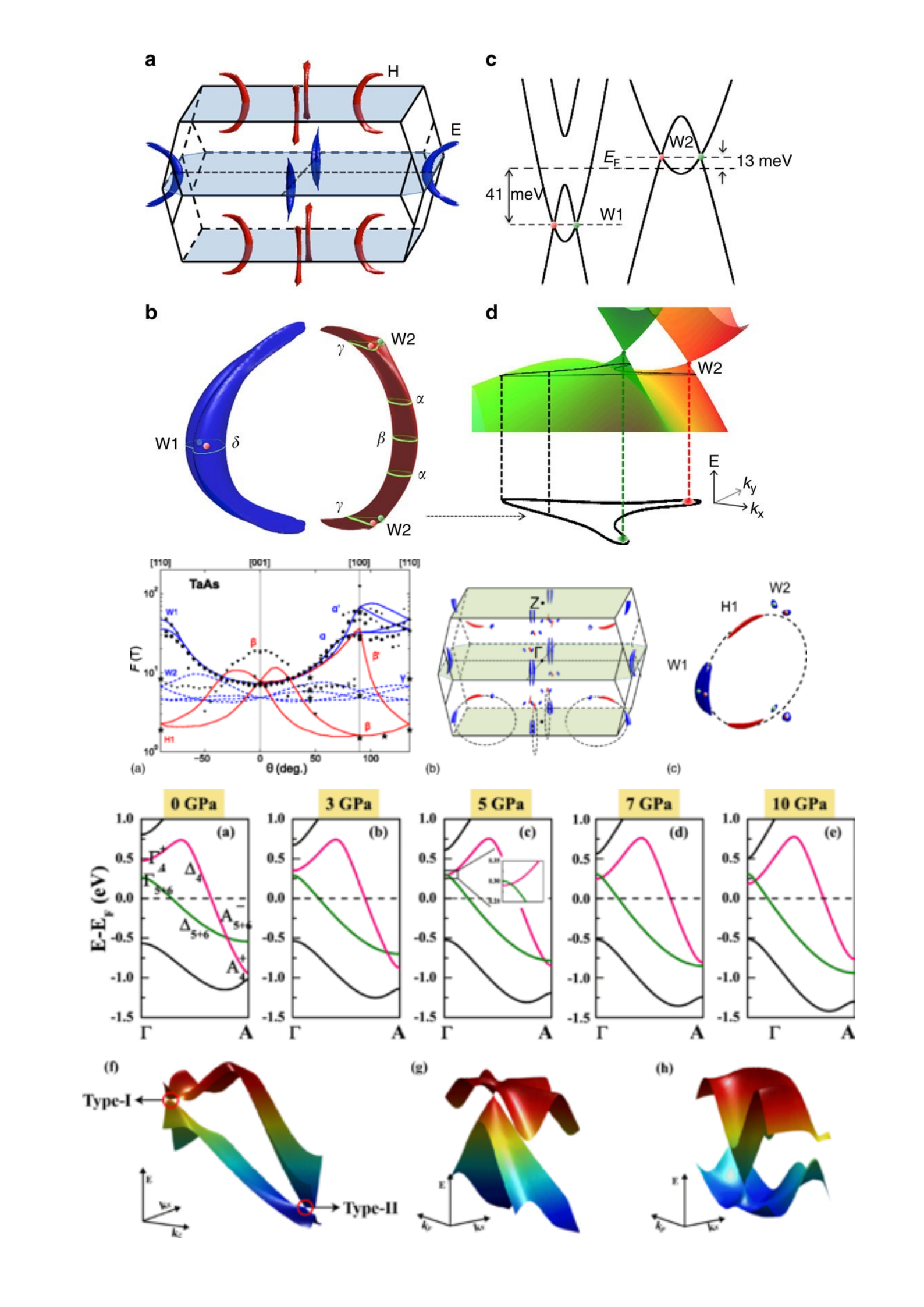

(a)
a
c
B
θ
(b)
FFT Amplitude (a. u.)
180°
0°
α
β γ
2β 2γ
δ
ε
0
1000
2000
F (T)
(c)
F (T)
2500
2000
1500
1000
500
0
90
180
θ (degrees)

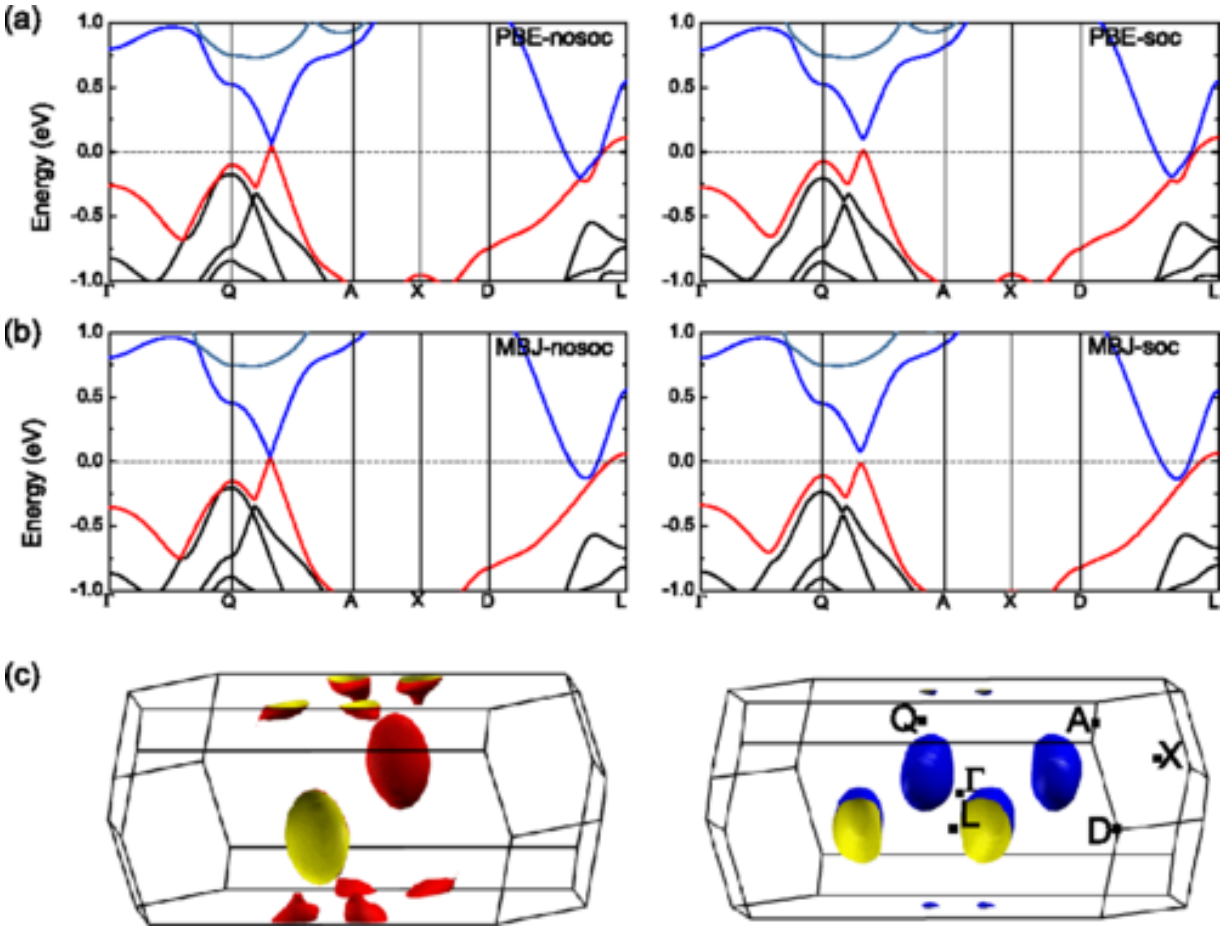

A
k_y=0 plane
Σ
S
k_x (π/a)
k_z (π/c)
B
k_z dispersion
k_x (π/a)
k_z (π/c)
C
k_y (π/a)
ARPES
k_x (π/a)
Cut 2
W2
Cut 1
Cal.
k_x
D
Weyl Fermions
Weyl +
Weyl −
E_B (eV)
k_y (Å^{-1})
E
Cut 2
W2
High
Low
E_B (eV)
k_z (π/c)
F
W2
k_z (π/c)
G
k_x-k_y FS at k_z=W1
Cut 3
k_y (π/a)
k_x (π/a)
H
Weyl Fermions
E_B (eV)
k_y (π/a)
I
Weyl Fermions W1
E_F
E_{W1}
k_y (π/a)
J
W1
W2
14 meV
Energy
k_x
k_x

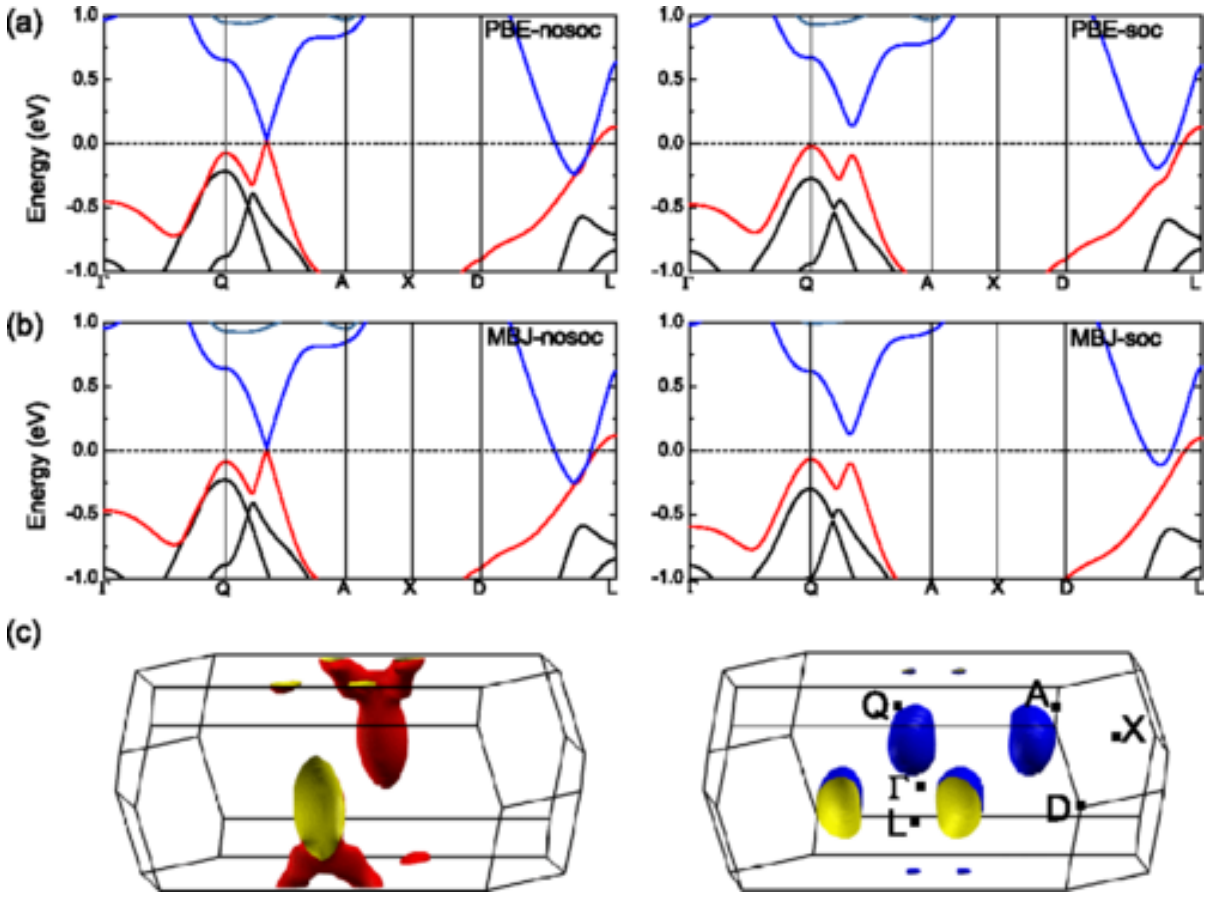

A
Co
S
Sn
C
Sn surface
Bulk
BZ2'
BZ1
BZ2''
Co surface
B
(001)
K̄
M̄
BZ2
BZ1
Γ̄
L
Γ
T
D
Sn
E
S
F
Co
height (Å)
1
-1
1 nm
G
H
I
dI/dV (au)
E (meV)
J
K
L
BZ1 BZ2
E (meV)
k∥ΓK
k∥ΓM (nm-1)
a
As
Pristine NbAs
Nb
Nb As
Intensity ×5
Intensity (a.u.)
Binding energy (eV)
b
E_B (eV)
k_y (1/Å)
k_x (1/Å)
Low High
Intensity (a.u.)
Low High
Surface contribution
c
Trivial SSs
TSSs
Trivial SSs
M̄ X̄ Γ̄ Ȳ M̄
d
E_b = 0 eV
E_b = 0.15 eV
E_b = 0.30 eV
k_y (1/Å)
k_x (1/Å)
e
Pristine
K-dosed
K
As
Nb
K 3p
Intensity
×5
Intensity (a.u.)
Binding energy (eV)
f
E_B (eV)
k_x (1/Å)
k_y (1/Å)
Low High
Intensity (a.u.)
Low High
Surface contribution
g
TSSs
TSSs
TSSs
TSSs
M̄ X̄ Γ̄ Ȳ M̄
h
E_b = 0 eV
E_b = 0.15 eV
E_b = 0.30 eV
k_y (1/Å)
k_x (1/Å)

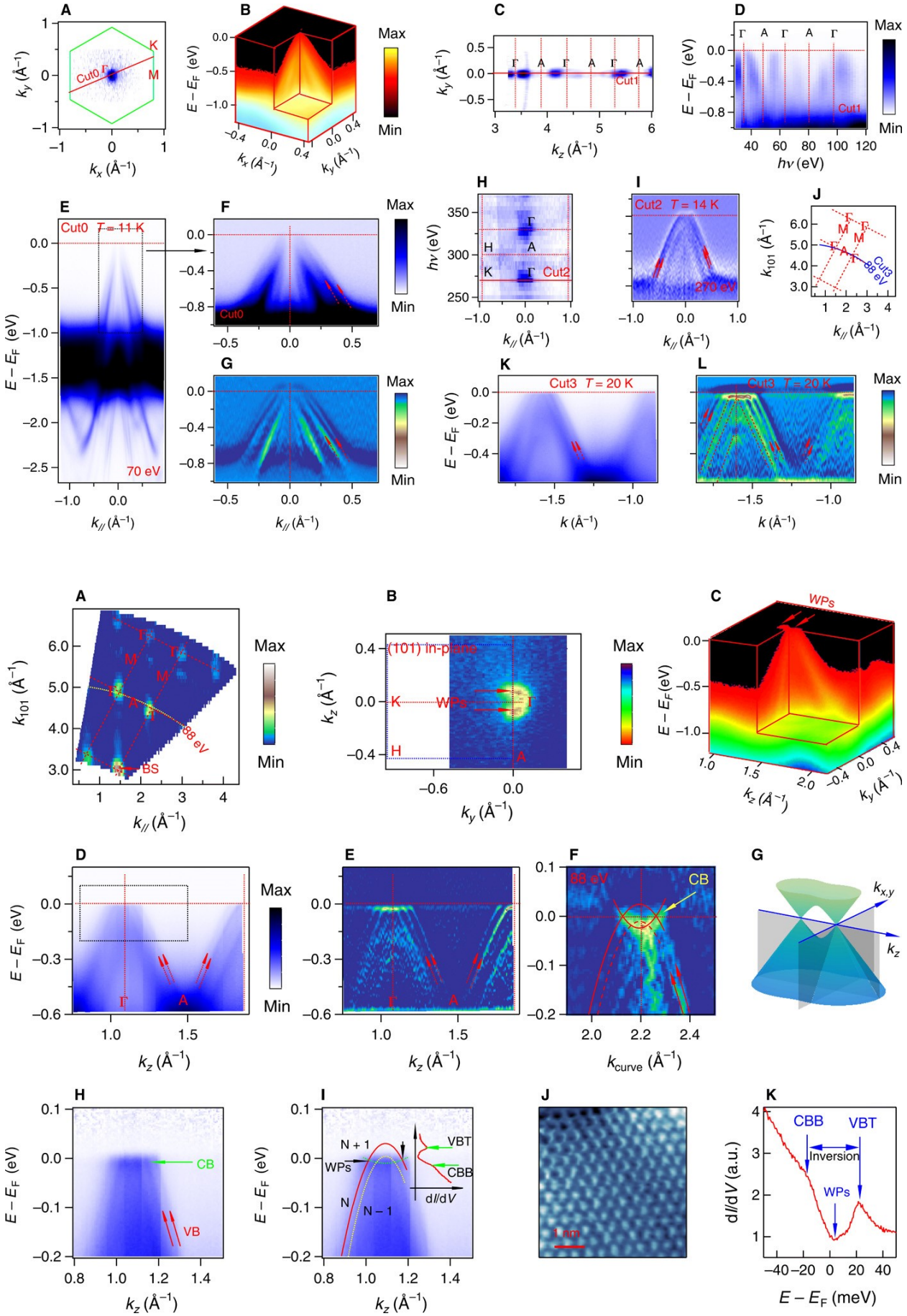

a
Pristine NbAs
Nb
As
Trivial SS
SFAs
b
Trivial SS
SFAs
c
Trivial SS
SFAs
d
Mirror plane
+WP
−WP
Surface BZ boundary
K Nb As
g
K-dosed NbAs
K
Nb
As
SFAs
SFAs
SFAs
h
SFAs
i
SFAs
j
SFAs
+WP
−WP
k_y (1/Å)
k_x (1/Å)
e
SFAs
−WP
+WP
Bulk Weyl dispersions
E_B (eV)
f
144 eV
172 eV
High
Intensity (a.u.)
Low
High
Surface contribution
Low
k
SFAs
−WP
+WP
Bulk Weyl dispersions
l
80 eV
96 eV

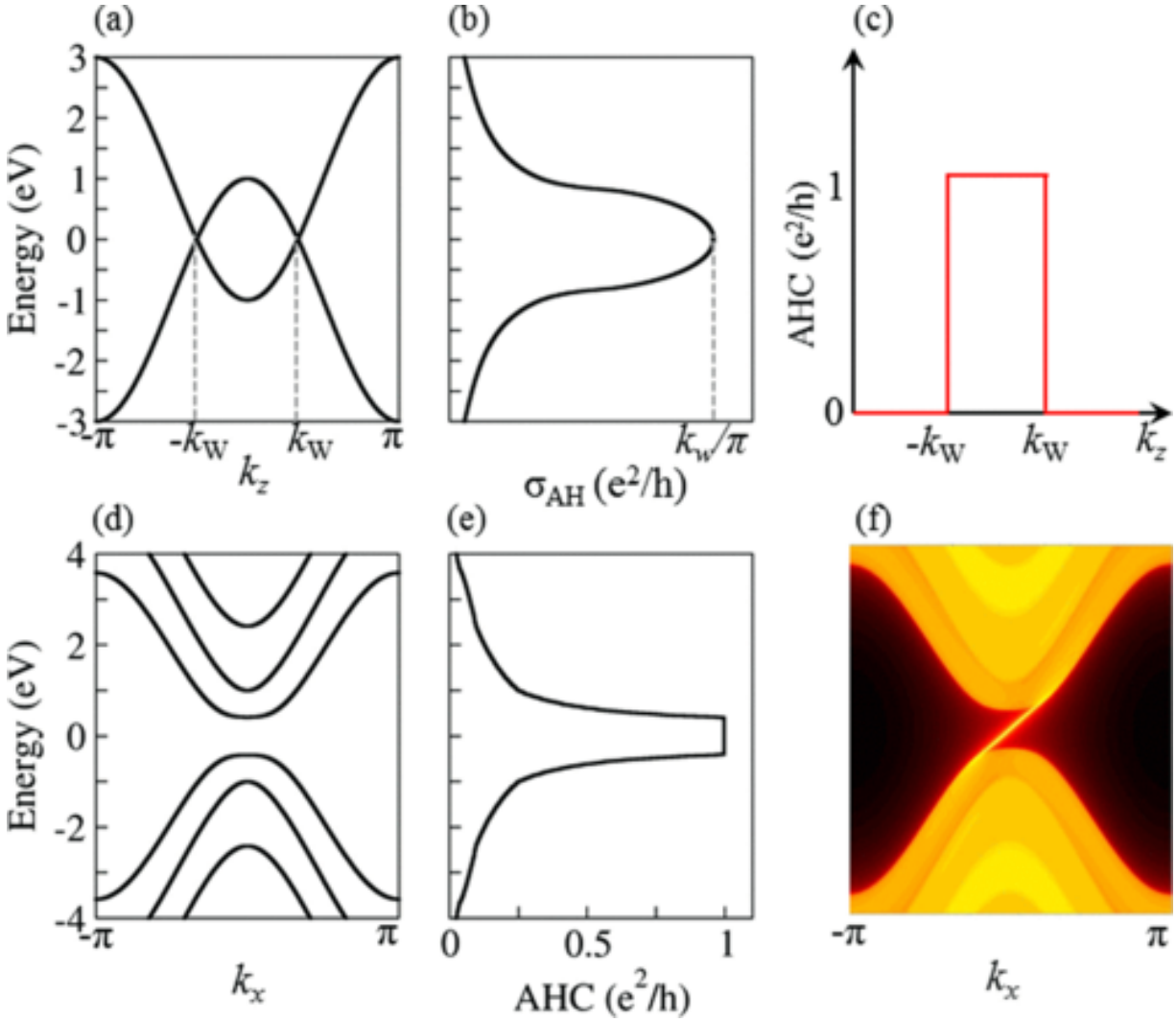

M
X
M
Γ
X
Γ
a
#1
#2
#3
E_F
b
E_F
SFAs
c
SFAs
High
Intensity (a.u.)
Low
High
Surface contribution
Low
d
E_F − 0.1 eV
e
#1
#2
#3
TSSs
TSSs
TSSs
TSSs
E_B (eV)
k_y (1/Å)
k_y (1/Å)
k_x (1/Å)

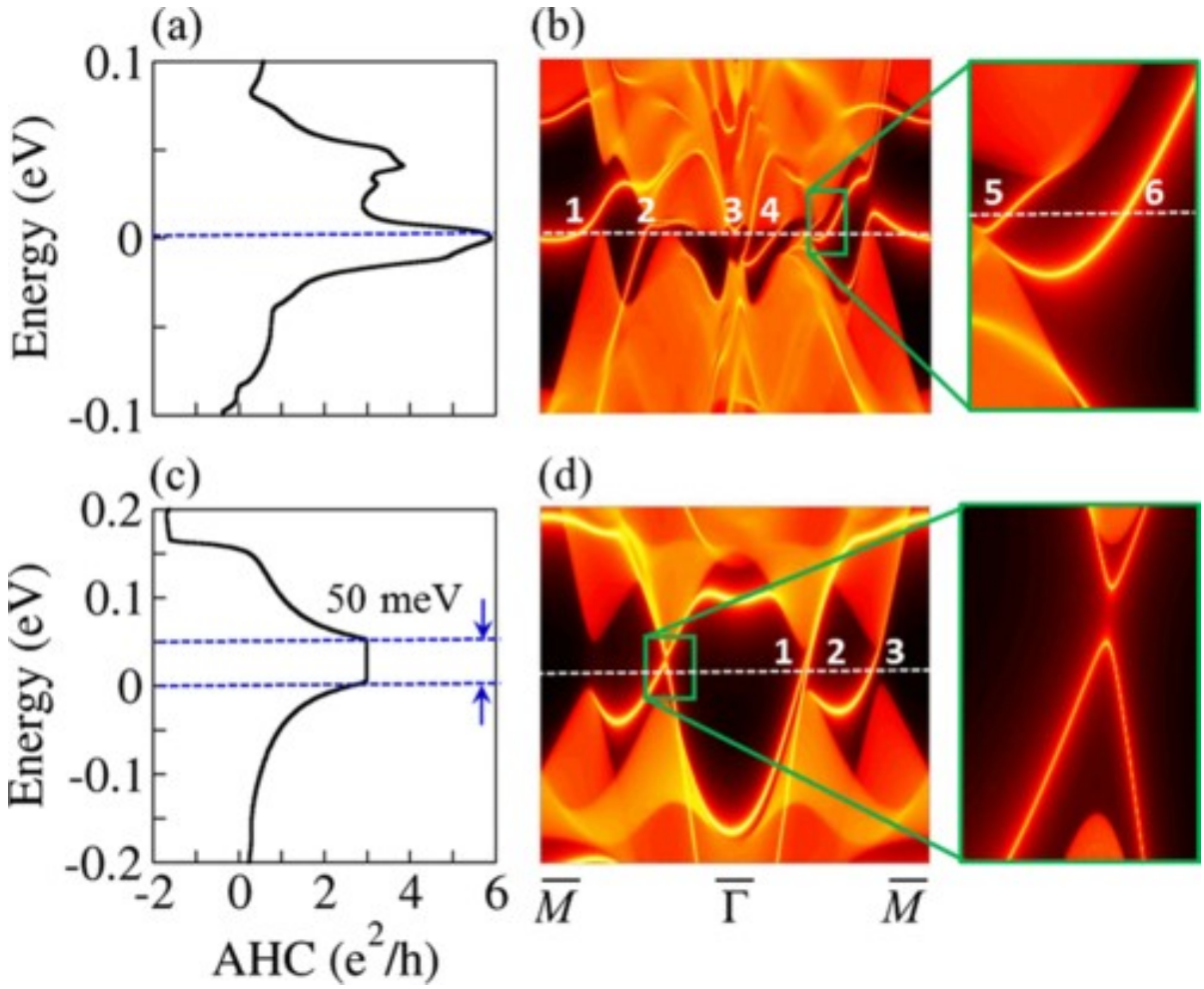

a
H
E
c
W2
E_F
13 meV
41 meV
W1
b
W2
γ
α
β
α
γ
W1
δ
W2
d
W2
E
k_y
k_x
[110]
[001]
[100]
[110]
TaAs
W1
W2
H1
α'
α
β
β'
γ
F (T)
θ (deg.)
(a)
Z
Γ
(b)
W2
H1
W1
(c)
0 GPa
3 GPa
5 GPa
7 GPa
10 GPa
(a)
(b)
(c)
(d)
(e)
E-E$_F$ (eV)
Γ
A
(f)
Type-I
Type-II
(g)
(h)

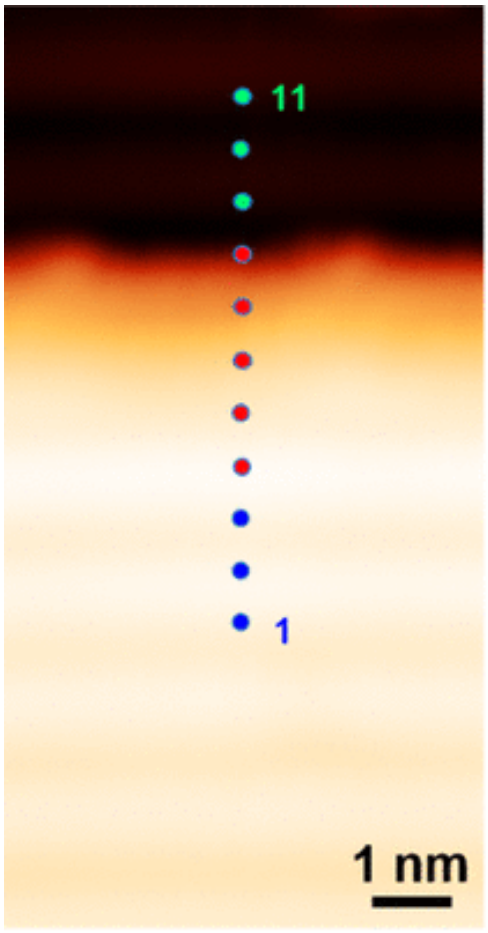

(a)
PBE-nosoc
PBE-soc
(b)
MBJ-nosoc
MBJ-soc
Energy (eV)
1.0
0.5
0.0
-0.5
-1.0
Γ
Q
A
X
D
L
(c)
Q
A
X
Γ
L
D

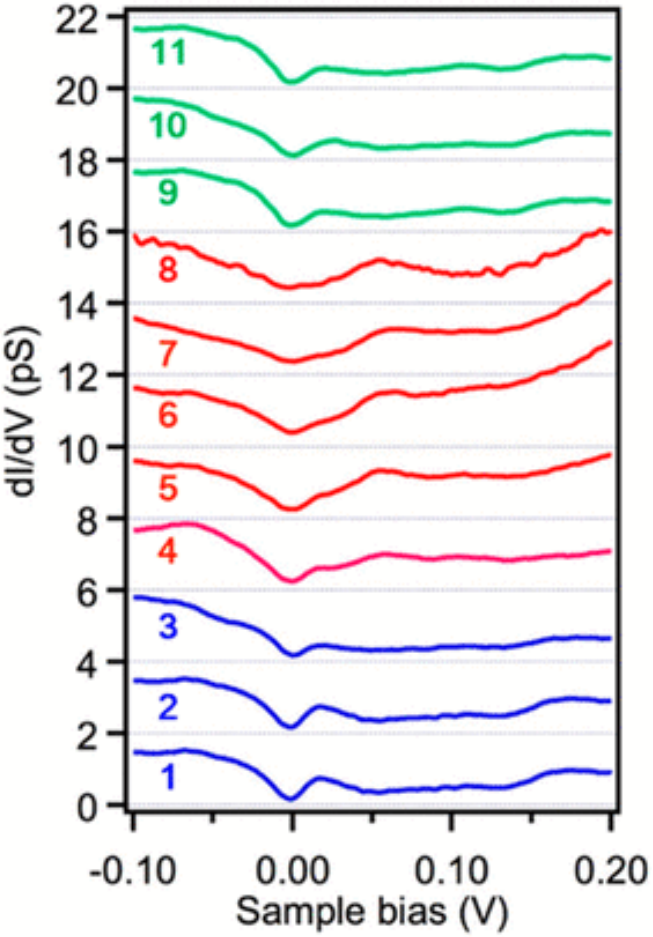

(a)
PBE-nosoc
PBE-soc
(b)
MBJ-nosoc
MBJ-soc
Energy (eV)
1.0
0.5
0.0
-0.5
-1.0
Γ
Q
A
X
D
L
(c)
Q
A
X
Γ
L
D

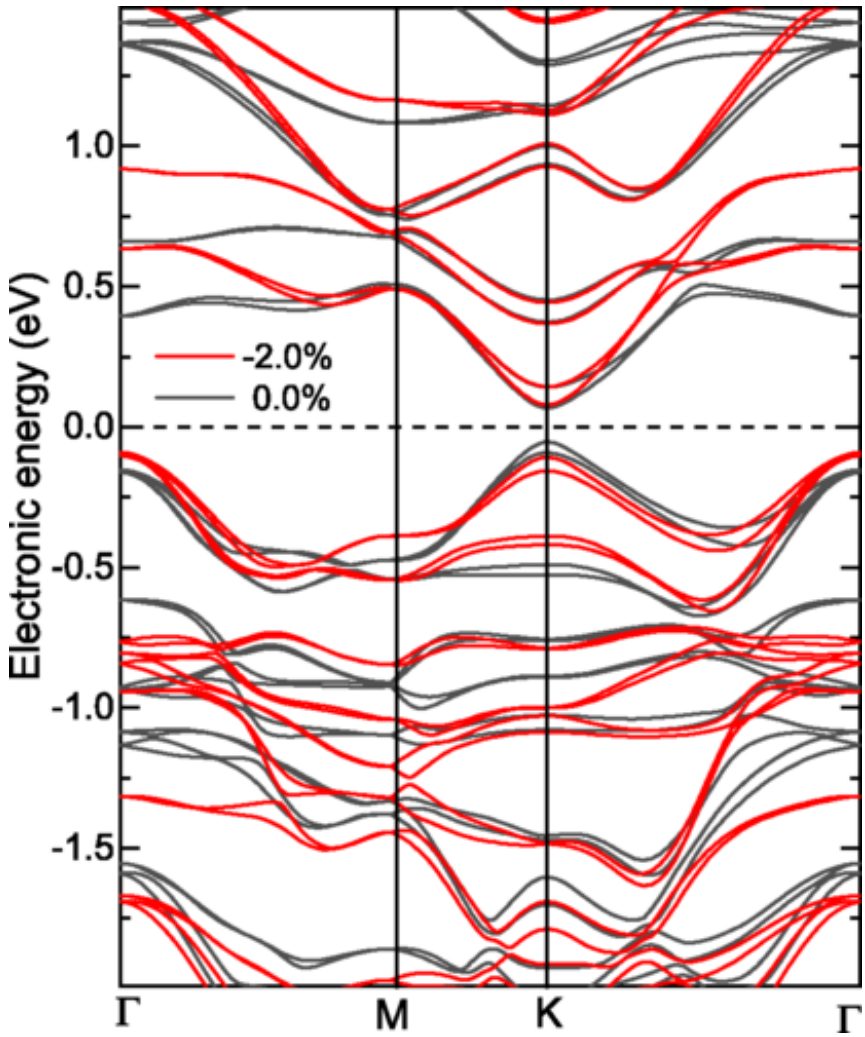

A
B
C
D
E
F
G
H
I
J
K
L
Cut0 T = 11 K
Cut1
Cut2 T = 14 K
Cut3 T = 20 K
70 eV
270 eV
88 eV
Max
Min
Γ
A
M
K
H
BS
(101) in-plane
WPs
CB
VB
VBT
CBB
N + 1
N
N − 1
dI/dV
Inversion
1 nm

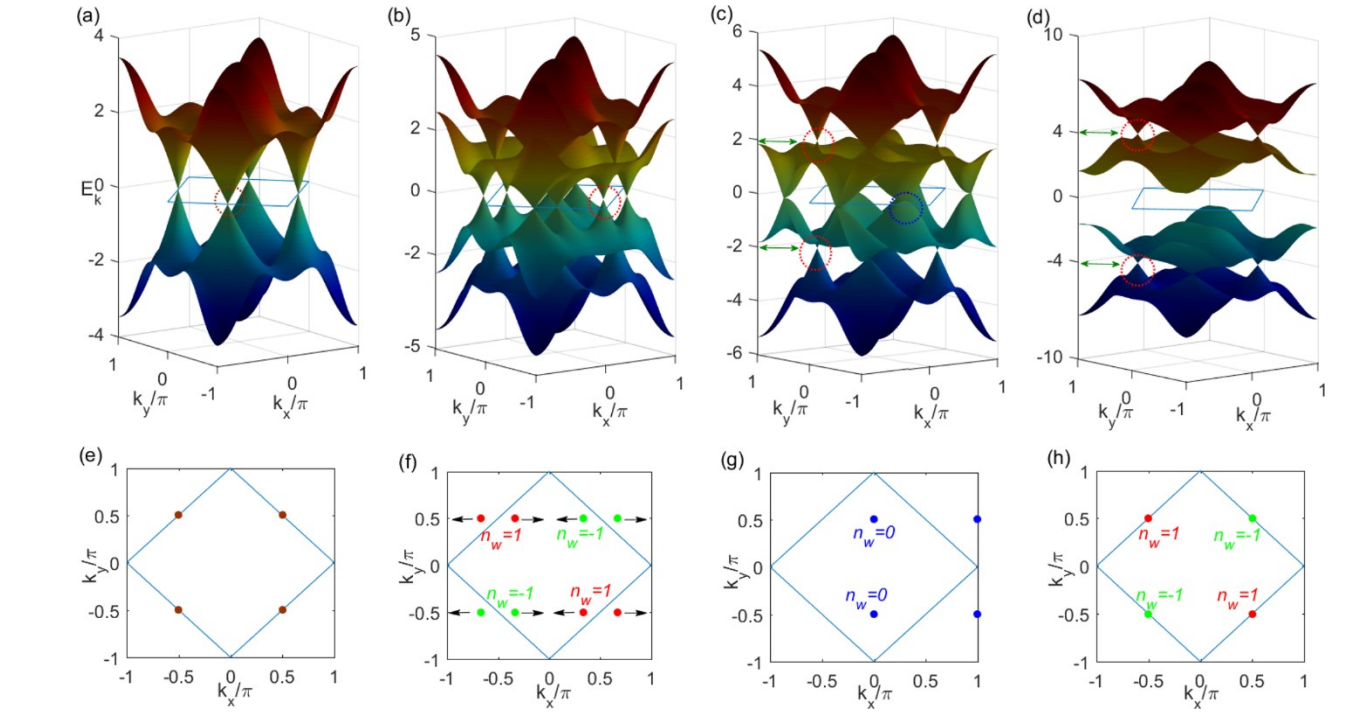

(a)
(b)
(c)
Energy (eV)
3
2
1
0
-1
-2
-3
-π
-k_W
k_W
π
k_z
σ_AH (e²/h)
k_w/π
AHC (e²/h)
1
0
-k_W
k_W
k_z
(d)
(e)
(f)
4
2
0
-2
-4
-π
π
k_x
0
0.5
1
AHC (e²/h)

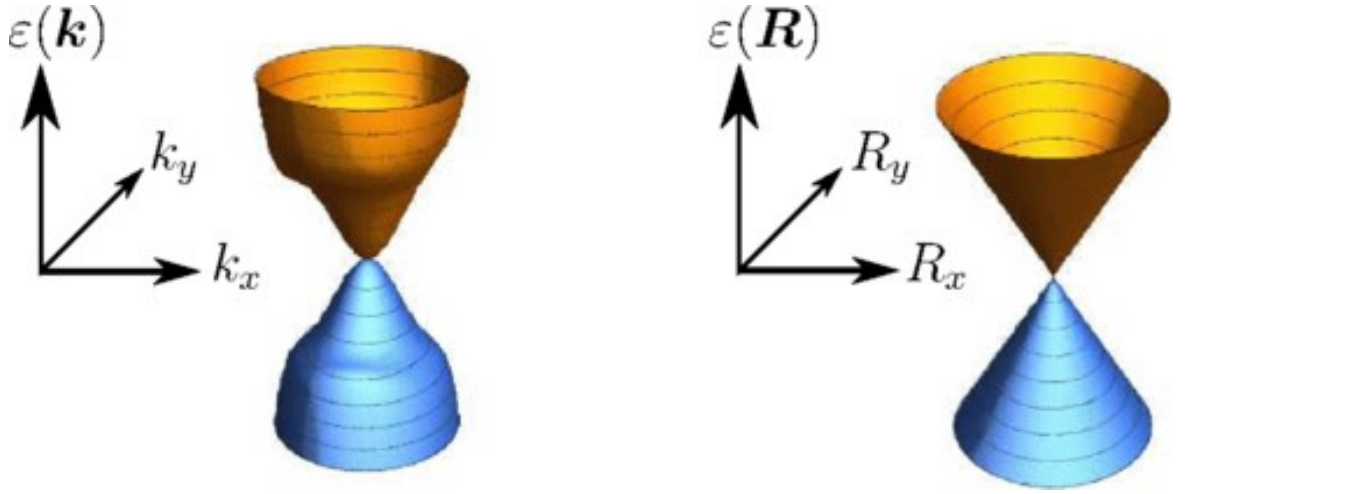

(a)
(b)
(c)
(d)
Energy (eV)
0.1
0
-0.1
0.2
0.1
0
-0.1
-0.2
50 meV
-2
0
2
4
6
AHC (e²/h)
1
2
3
4
5
6
M̄
Γ̄
M̄

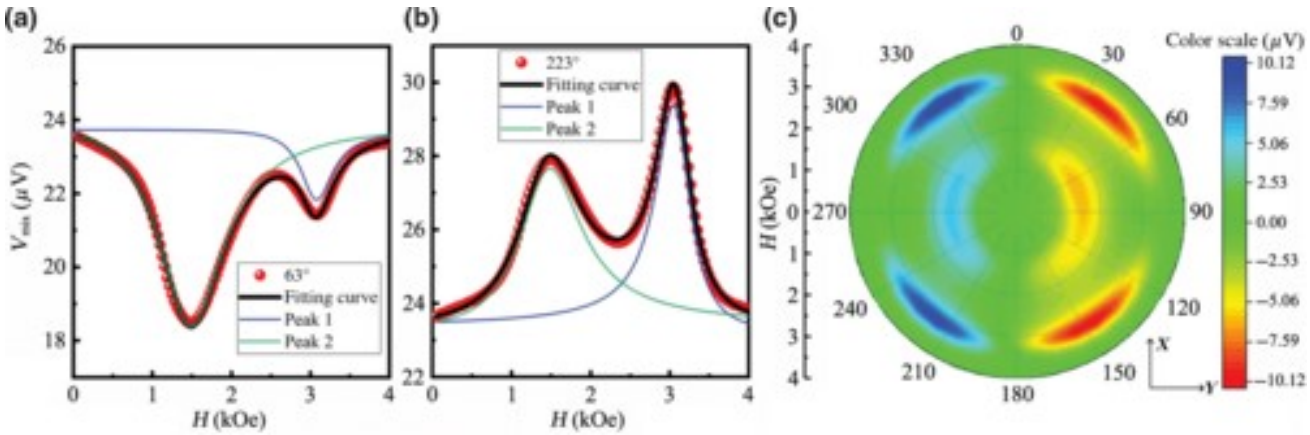

11
1
1 nm

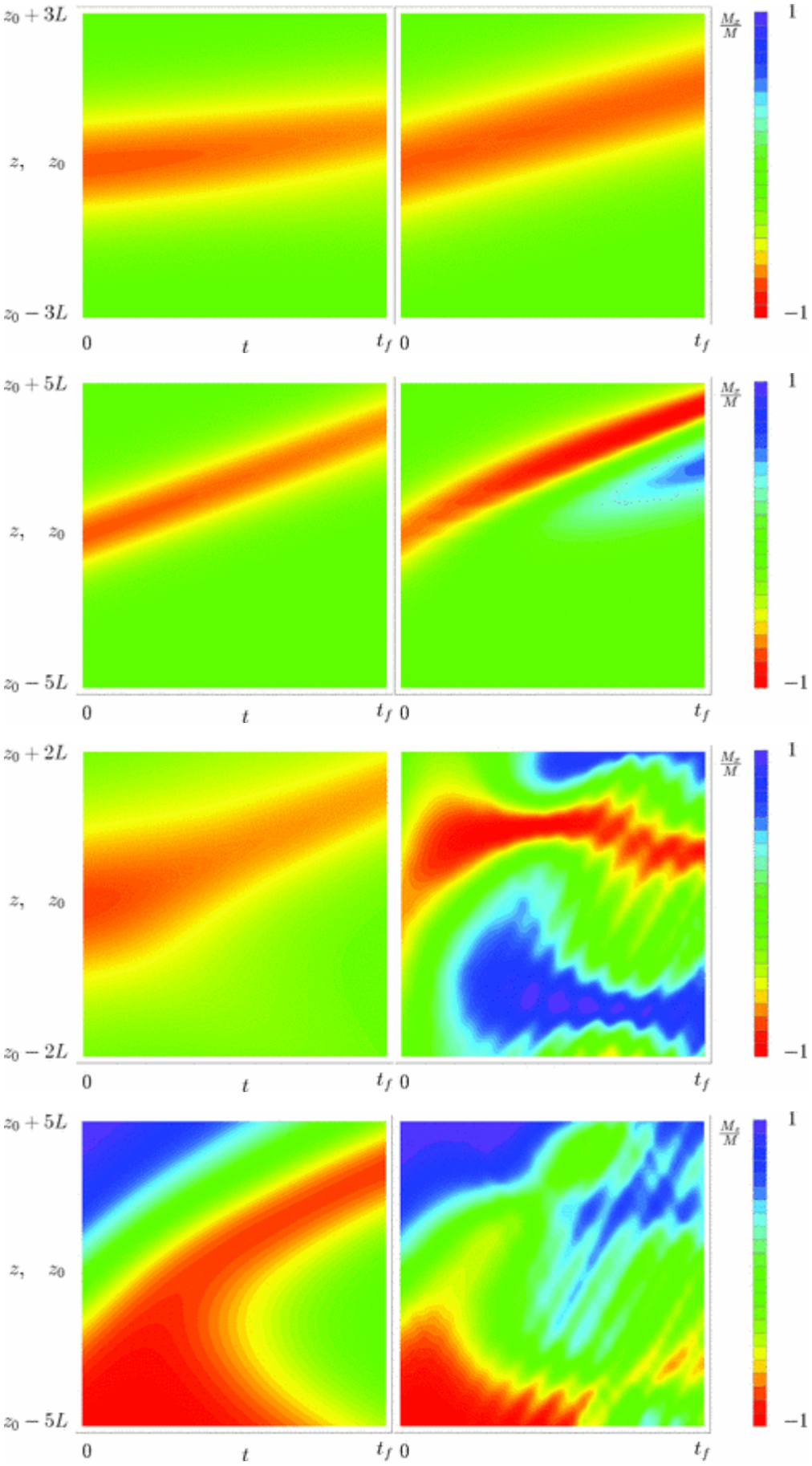

dI/dV (pS)
Sample bias (V)
11
10
9
8
7
6
5
4
3
2
1
22
20
18
16
14
12
10
8
6
4
2
0
-0.10
0.00
0.10
0.20

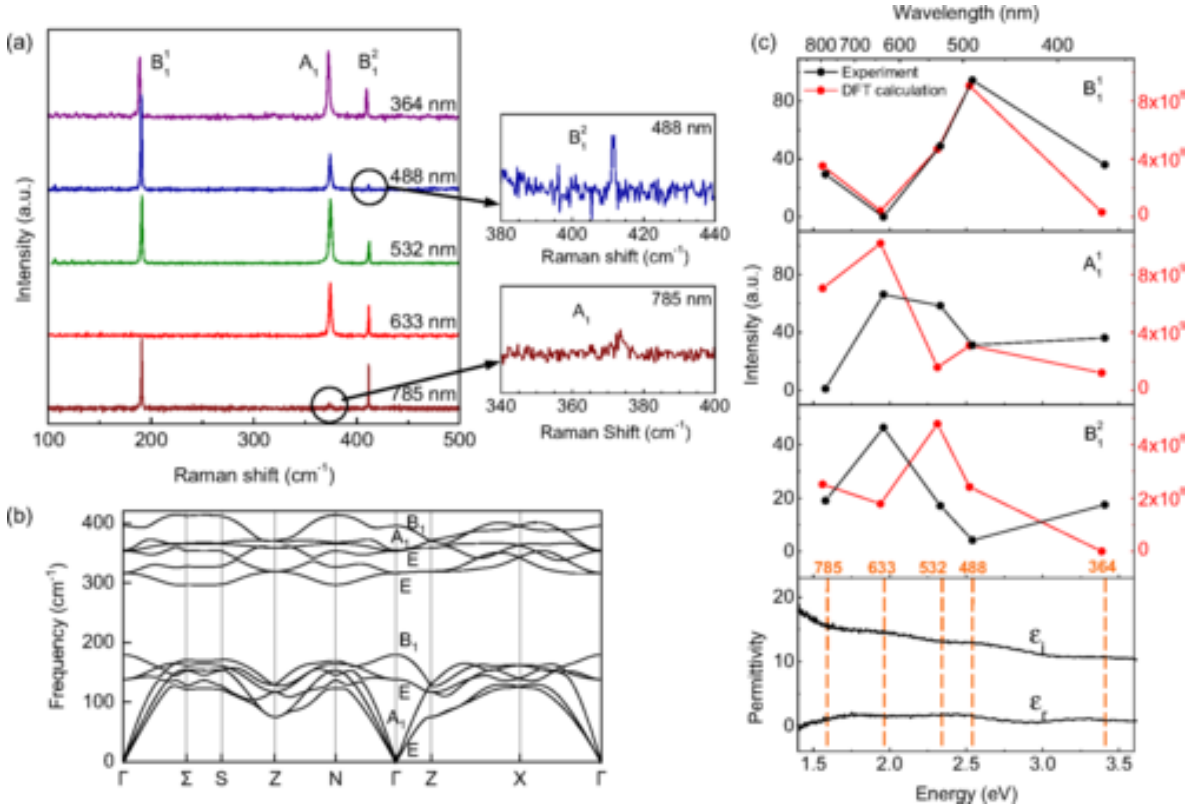

Electronic energy (eV)
-2.0%
0.0%
1.0
0.5
0.0
-0.5
-1.0
-1.5
Γ
M
K
Γ

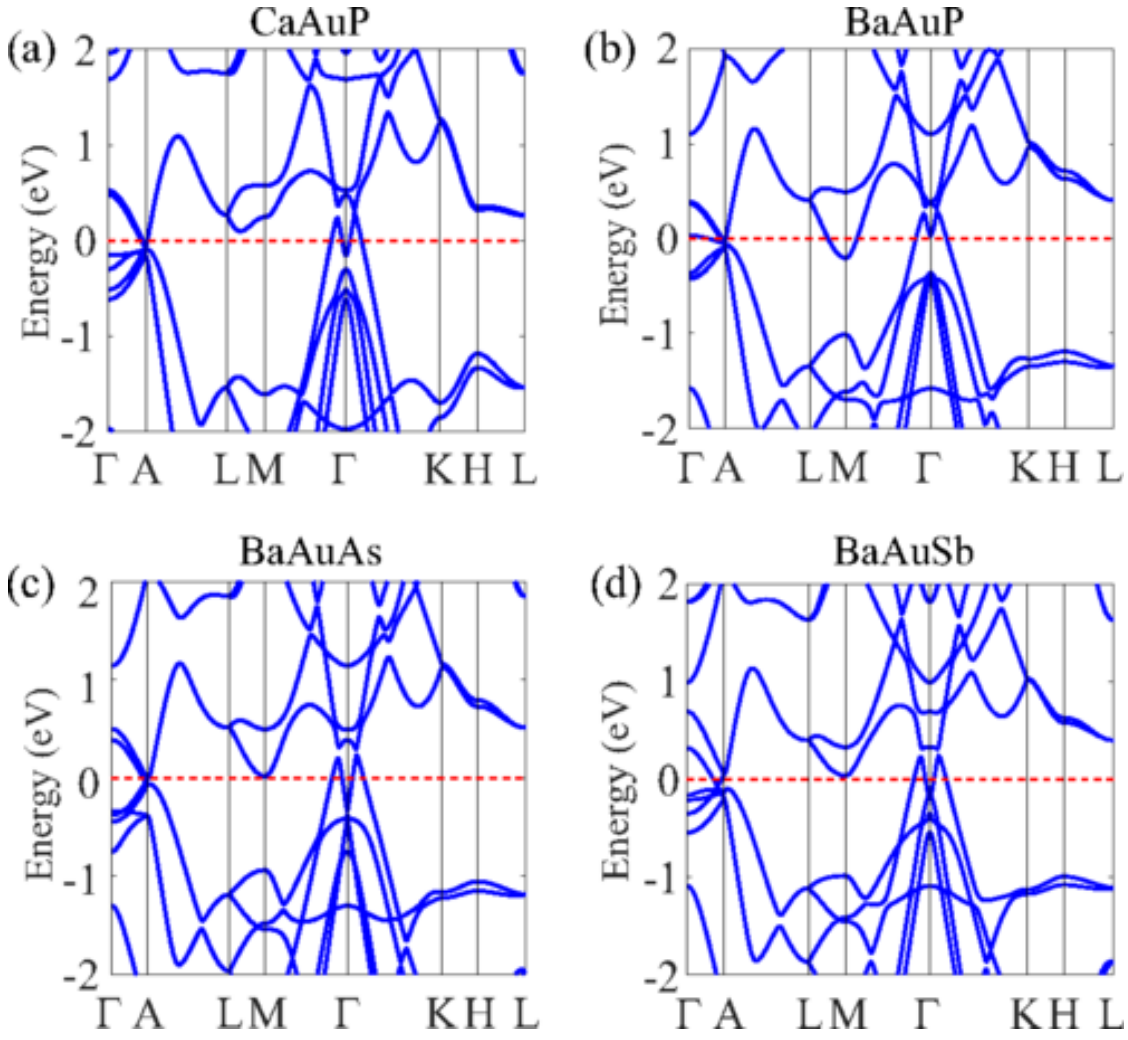

(a)
(b)
(c)
(d)
(e)
(f)
(g)
(h)
E_k^0
k_y/π
k_x/π
n_w=1
n_w=-1
n_w=0

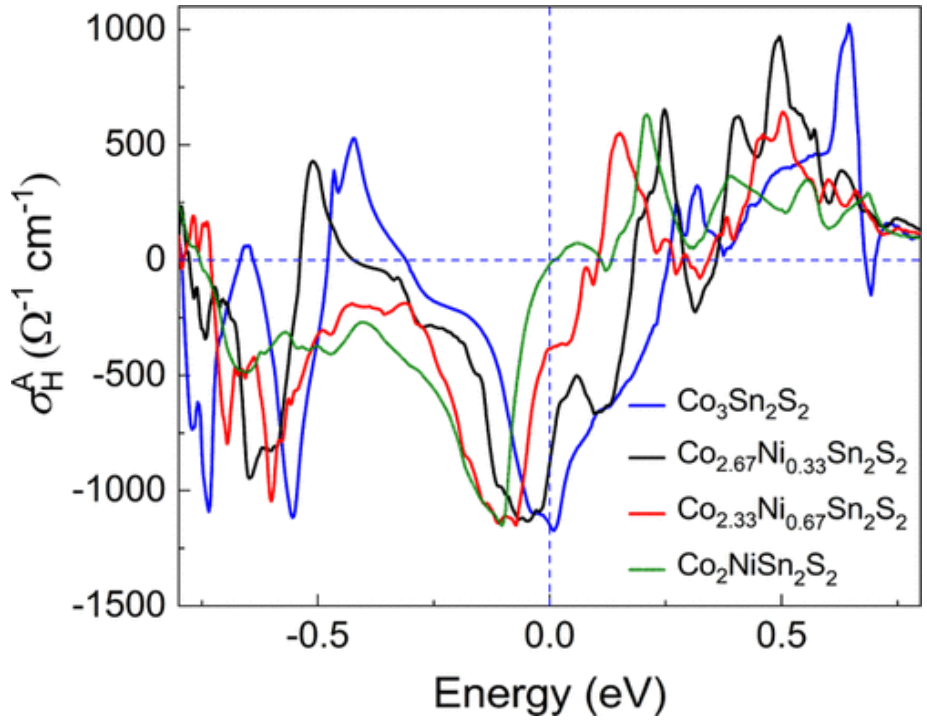

$\varepsilon(\boldsymbol{k})$
k_y
k_x
$\varepsilon(\boldsymbol{R})$
R_y
R_x

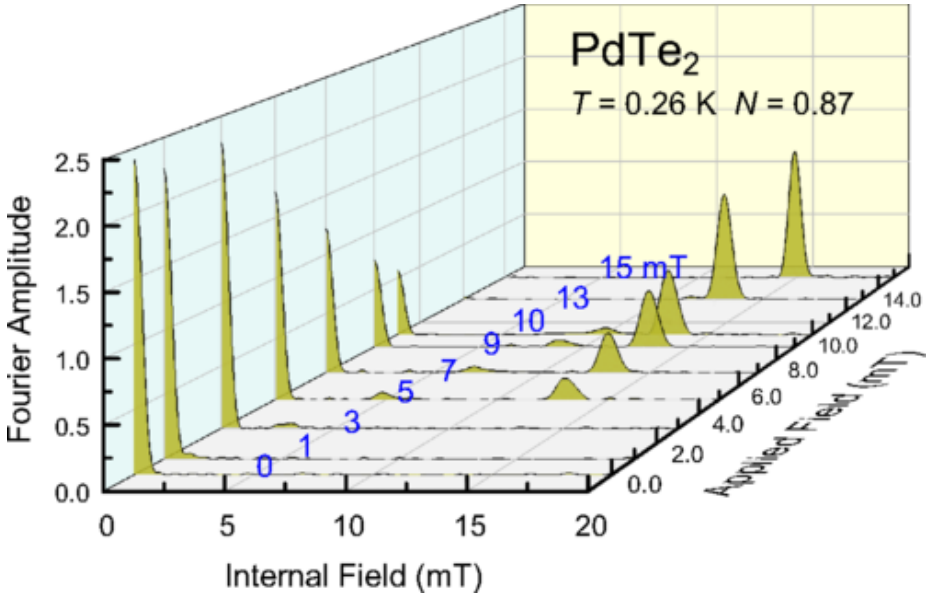

(a)
(b)
(c)
V_{sm} (μV)
H (kOe)
63°
223°
Fitting curve
Peak 1
Peak 2
Color scale (μV)
10.12
7.59
5.06
2.53
0.00
−2.53
−5.06
−7.59
−10.12

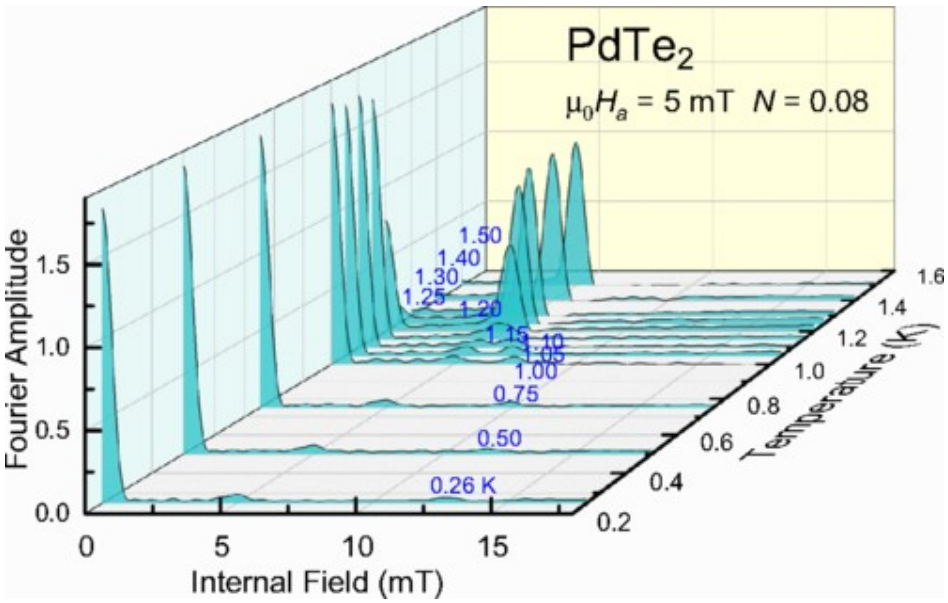

$z_0 + 3L$
$z, \quad z_0$
$z_0 - 3L$
0
t
t_f
0
t_f
$\frac{M_z}{M}$
1
−1
$z_0 + 5L$
$z, \quad z_0$
$z_0 - 5L$
0
t
t_f
0
t_f
$\frac{M_z}{M}$
1
−1
$z_0 + 2L$
$z, \quad z_0$
$z_0 - 2L$
0
t
t_f
0
t_f
$\frac{M_z}{M}$
1
−1
$z_0 + 5L$
$z, \quad z_0$
$z_0 - 5L$
0
t
t_f
0
t_f
$\frac{M_z}{M}$
1
−1

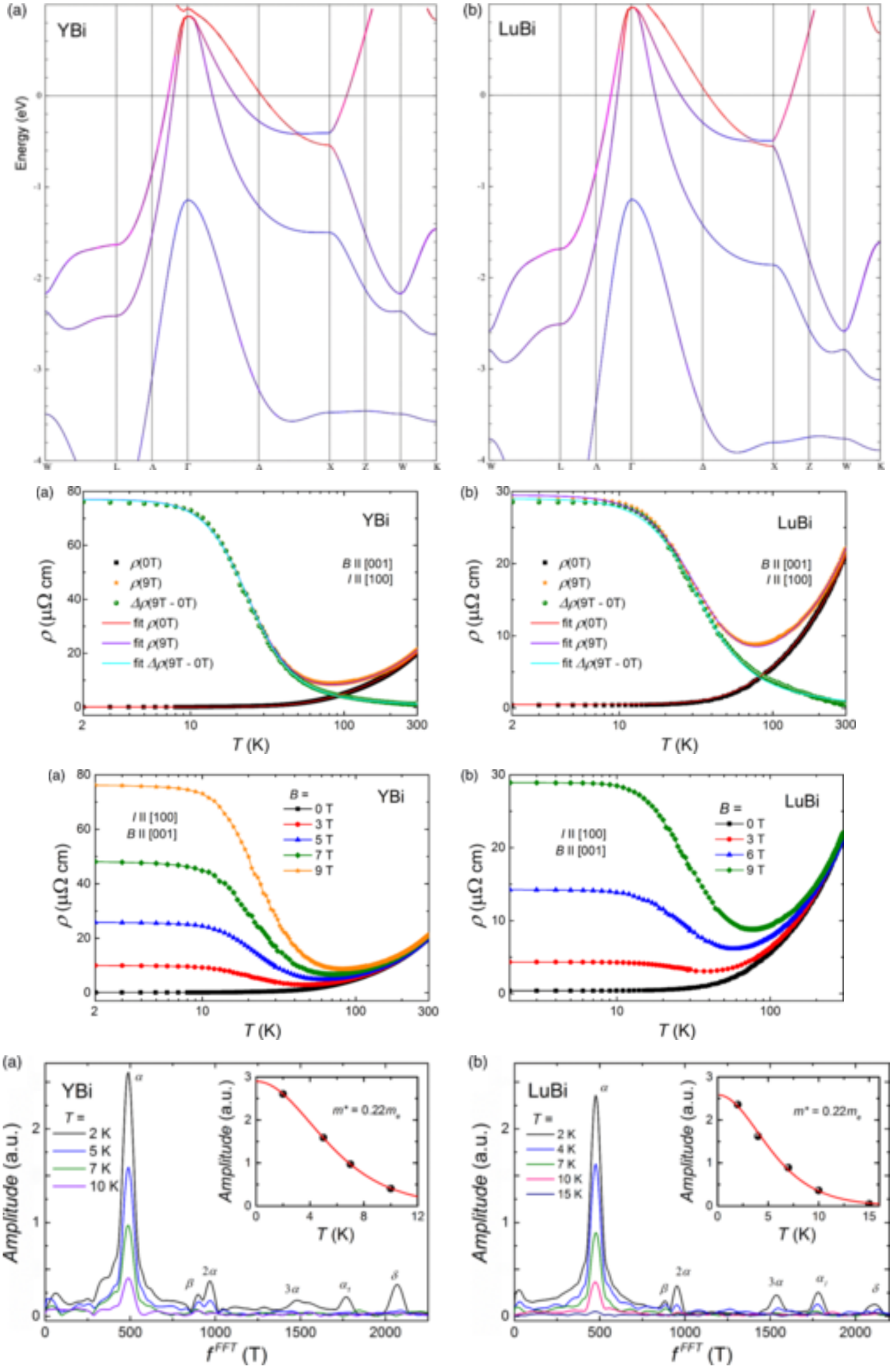

(a)
Intensity (a.u.)
364 nm
488 nm
532 nm
633 nm
785 nm
Raman shift (cm-1)
(b)
Frequency (cm-1)
Γ Σ S Z N Γ Z X Γ
(c)
Wavelength (nm)
Experiment
DFT calculation
Intensity (a.u.)
Permittivity
Energy (eV)

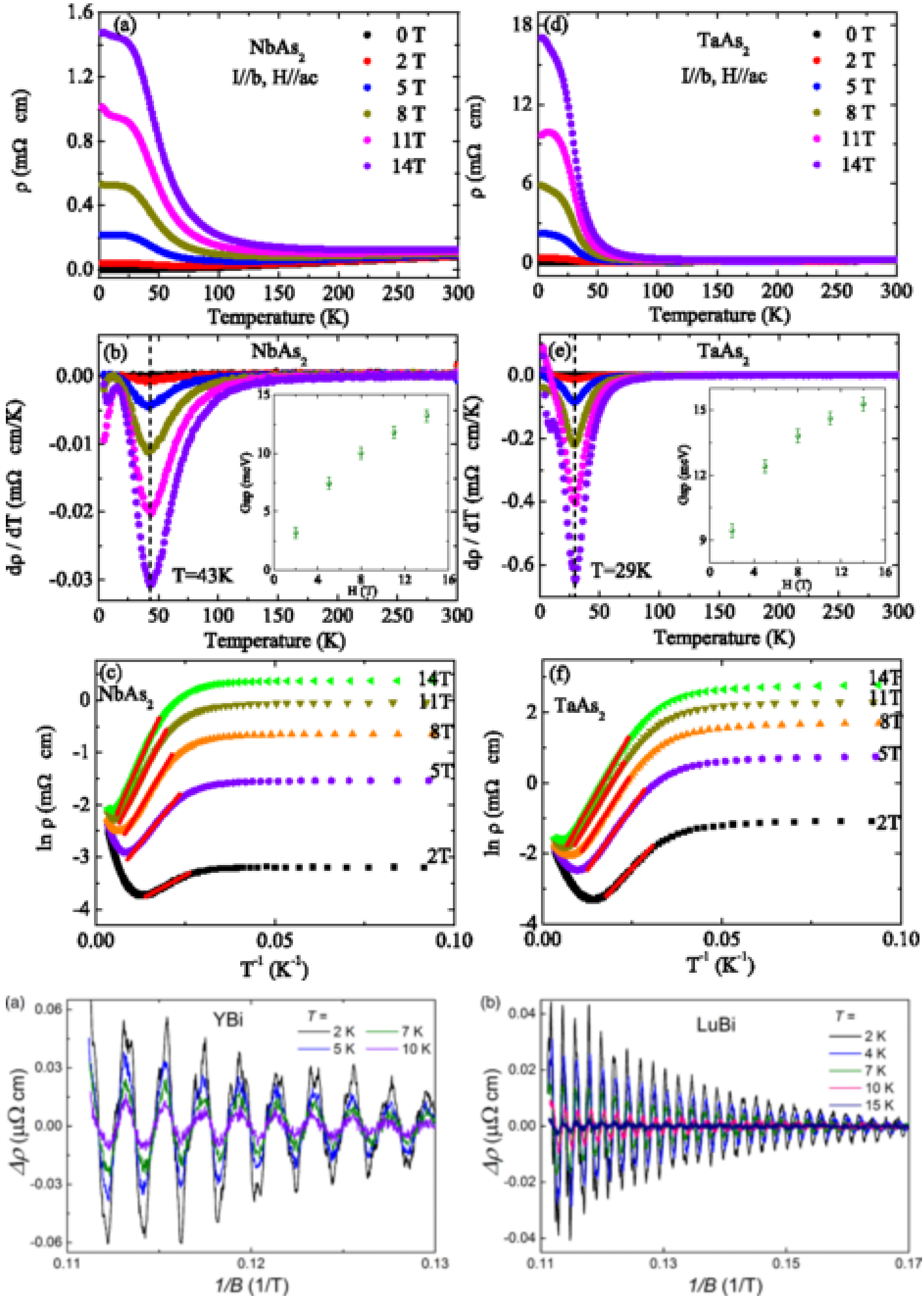

CaAuP
BaAuP
BaAuAs
BaAuSb
Energy (eV)
Γ A LM Γ KH L

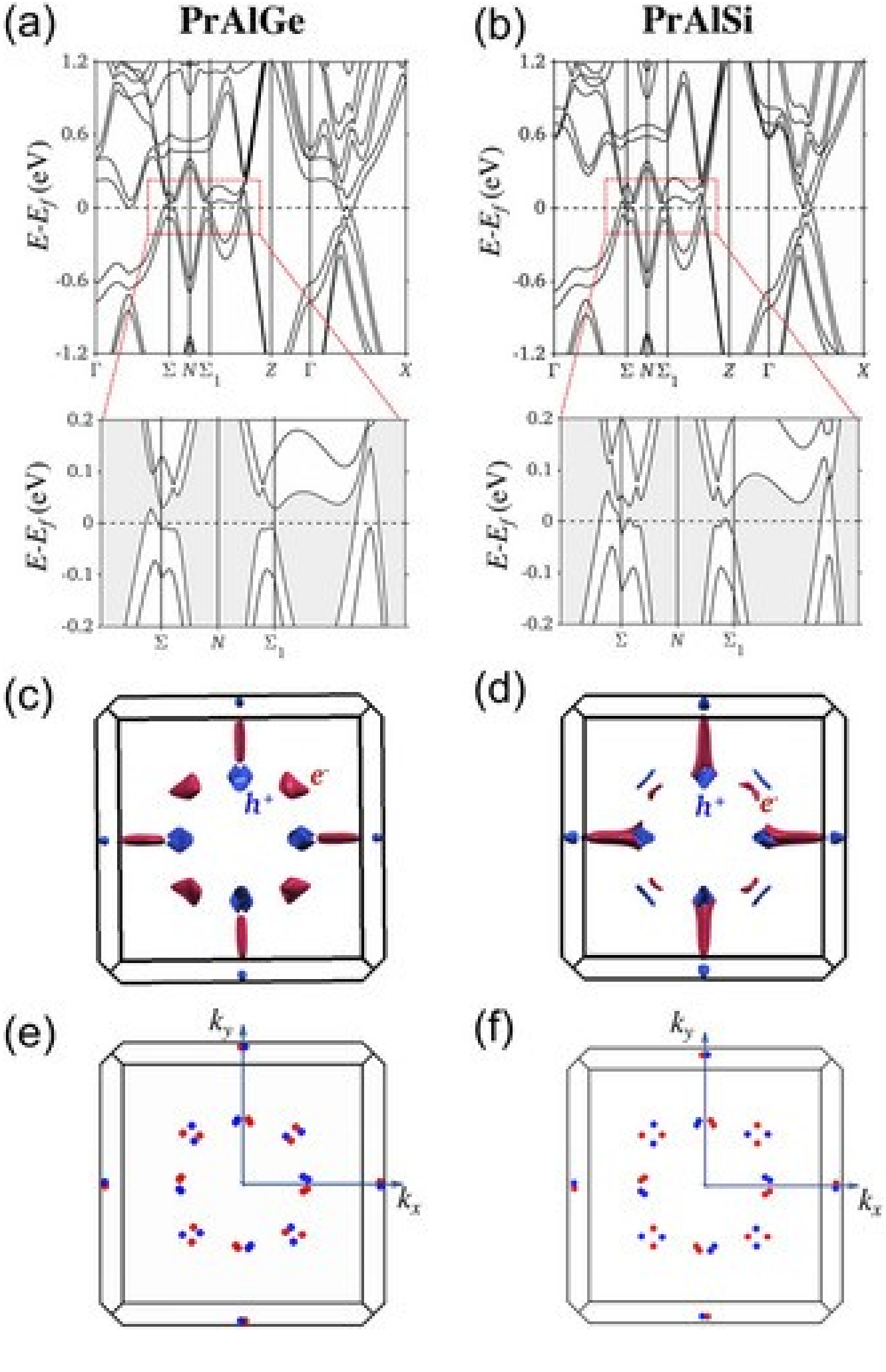

1000
500
0
-500
-1000
-1500
σ_H^A (Ω^{-1} cm^{-1})
-0.5
0.0
0.5
Energy (eV)
$Co_3Sn_2S_2$
$Co_{2.67}Ni_{0.33}Sn_2S_2$
$Co_{2.33}Ni_{0.67}Sn_2S_2$
$Co_2NiSn_2S_2$

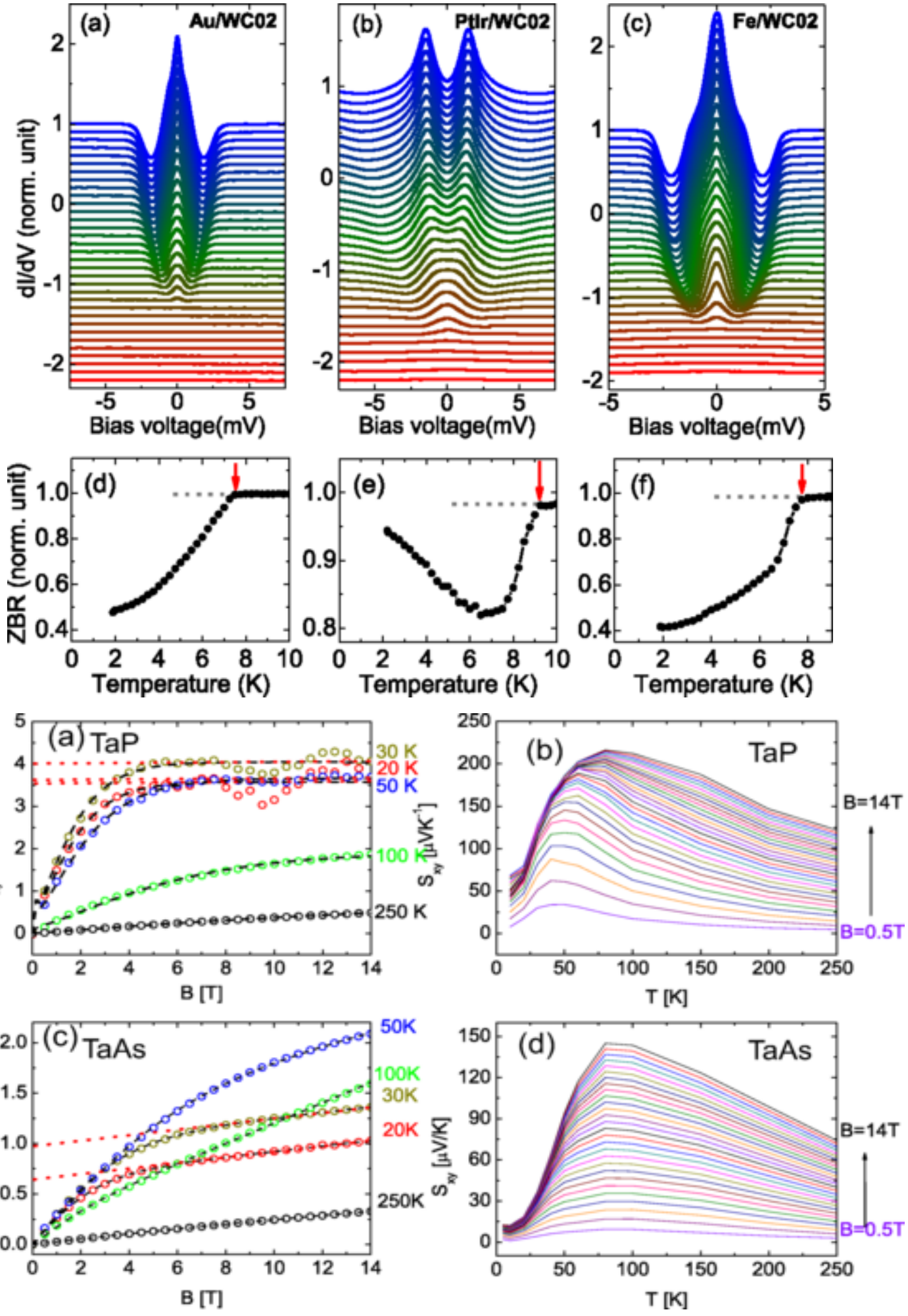

PdTe$_2$
T = 0.26 K N = 0.87
Fourier Amplitude
Internal Field (mT)
Applied Field (mT)
0
1
3
5
7
9
10
13
15 mT

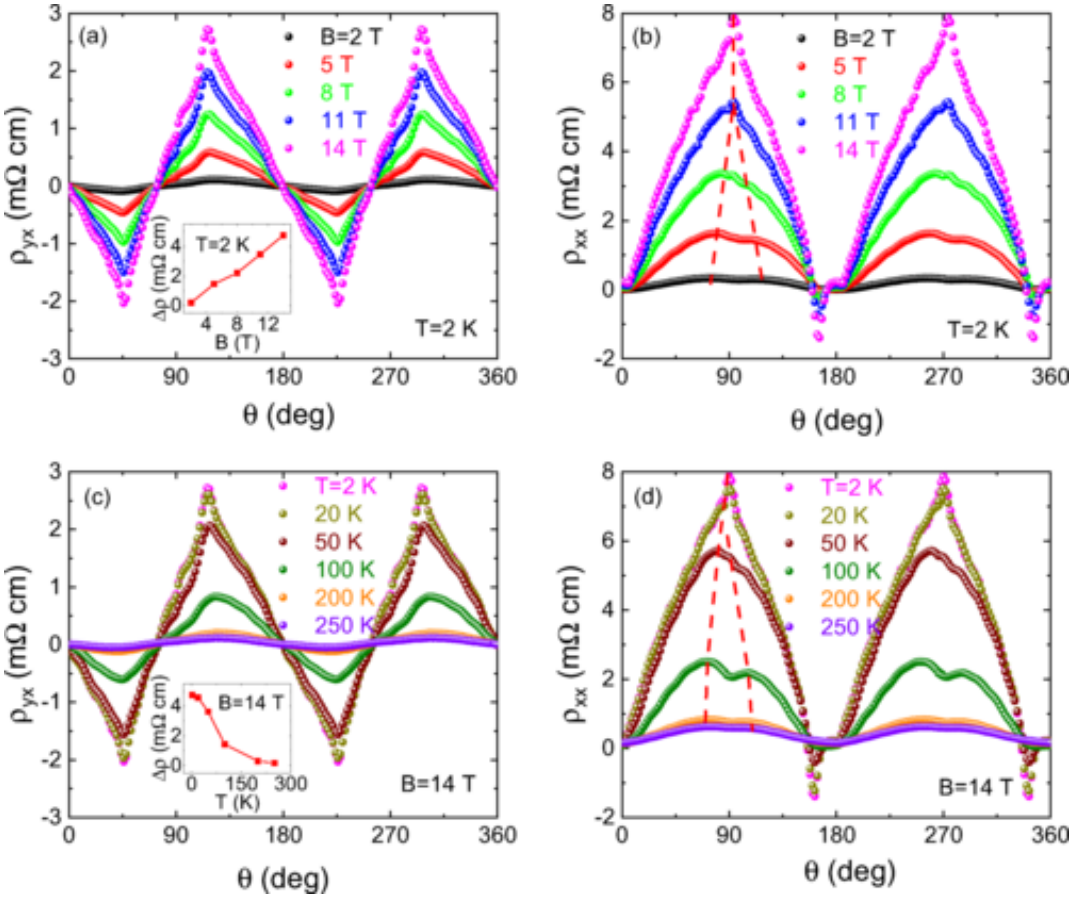

PdTe$_2$
$\mu_0 H_a$ = 5 mT N = 0.08
Fourier Amplitude
Internal Field (mT)
Temperature (K)
0.26 K
0.50
0.75
1.00
1.05
1.10
1.15
1.20
1.25
1.30
1.40
1.50

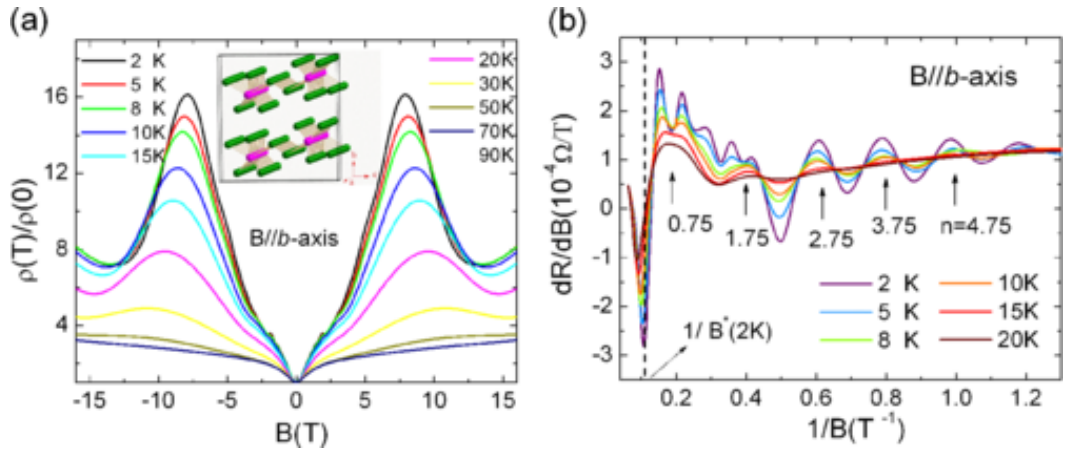

(a)
YBi
(b)
LuBi
Energy (eV)
W L Λ Γ Δ X Z W K
(a)
YBi
(b)
LuBi
ρ (μΩ cm)
ρ(0T)
ρ(9T)
Δρ(9T - 0T)
fit ρ(0T)
fit ρ(9T)
fit Δρ(9T - 0T)
B II [001]
I II [100]
T (K)
(a)
YBi
(b)
LuBi
I II [100]
B II [001]
B =
0 T
3 T
5 T
6 T
7 T
9 T
ρ (μΩ cm)
T (K)
(a)
YBi
(b)
LuBi
Amplitude (a.u.)
T =
2 K
4 K
5 K
7 K
10 K
15 K
α
β
2α
3α
α_z
δ
m* = 0.22m_e
T (K)
f^FFT (T)

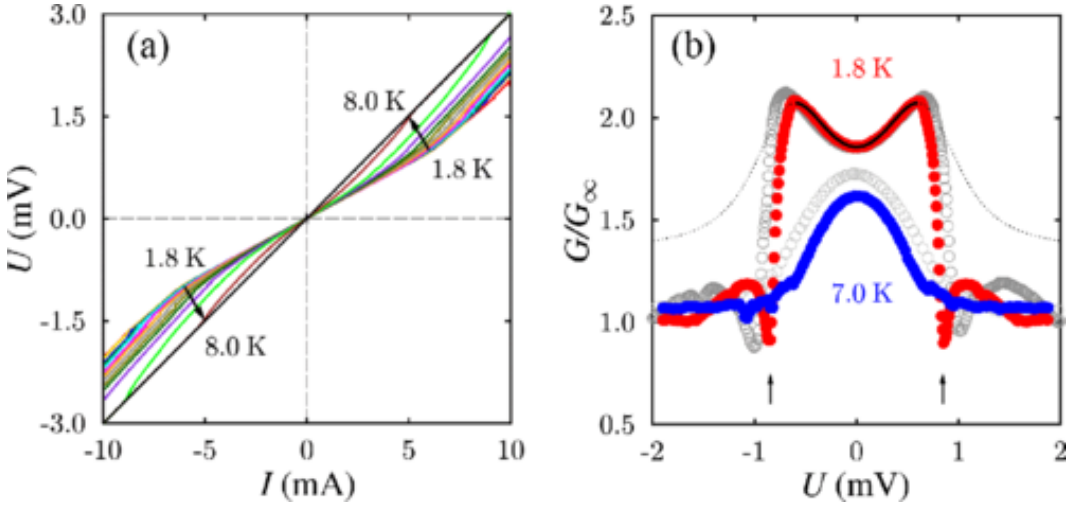

(a)
NbAs2
I//b, H//ac
0 T
2 T
5 T
8 T
11T
14T
ρ (mΩ cm)
Temperature (K)
(d)
TaAs2
I//b, H//ac
(b)
NbAs2
T=43K
dρ / dT (mΩ cm/K)
Gap (meV)
H (T)
(e)
TaAs2
T=29K
(c)
NbAs2
ln ρ (mΩ cm)
T-1 (K-1)
(f)
TaAs2
(a)
YBi
T =
2 K
5 K
7 K
10 K
Δρ (μΩ cm)
1/B (1/T)
(b)
LuBi
2 K
4 K
7 K
10 K
15 K

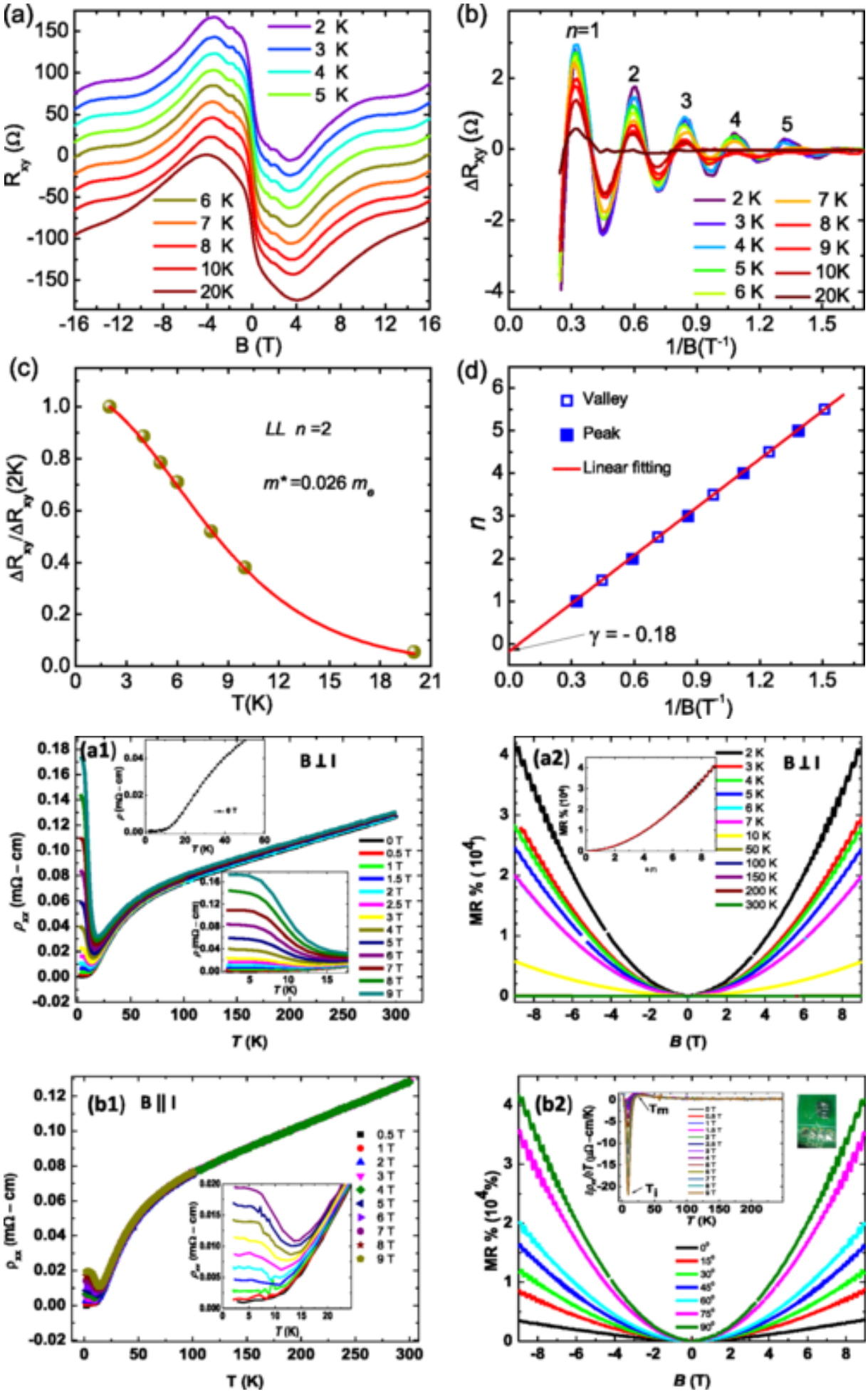

(a)
PrAlGe
(b)
PrAlSi
E-E_f (eV)
1.2
0.6
0
-0.6
-1.2
Γ
Σ
N
Σ_1
Z
Γ
X
0.2
0.1
0
-0.1
-0.2
Σ
N
Σ_1
(c)
(d)
h+
e-
(e)
(f)
k_y
k_x

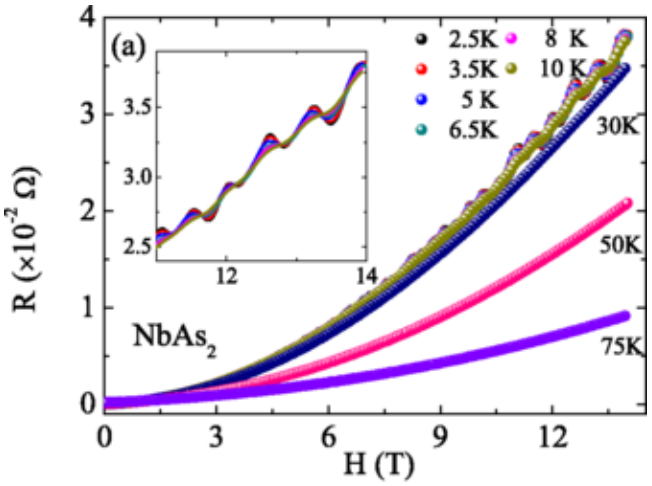

(a)
Au/WC02
(b)
PtIr/WC02
(c)
Fe/WC02
dI/dV (norm. unit)
Bias voltage(mV)
Bias voltage(mV)
Bias voltage(mV)
(d)
(e)
(f)
ZBR (norm. unit)
Temperature (K)
Temperature (K)
Temperature (K)
(a) TaP
30 K
20 K
50 K
100 K
250 K
S_xy/T [μVK^-2]
B [T]
(b) TaP
B=14T
B=0.5T
S_xy [μVK^-1]
T [K]
(c) TaAs
50K
100K
30K
20K
250K
S_xy/T [μVK^-2]
B [T]
(d) TaAs
B=14T
B=0.5T
S_xy [μV/K]
T [K]

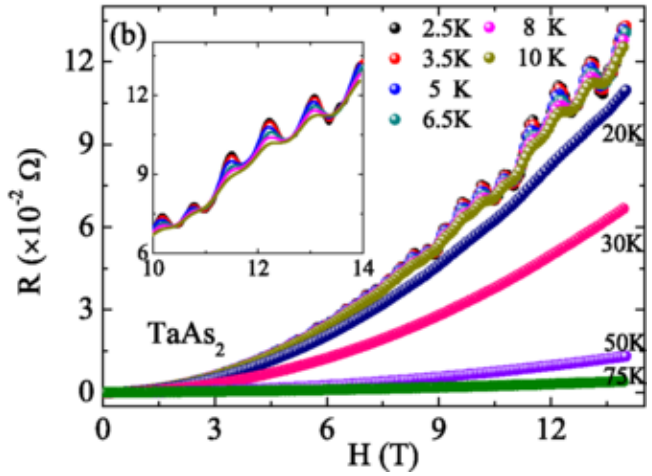

(a)
B=2 T
5 T
8 T
11 T
14 T
T=2 K
ρyx (mΩ cm)
θ (deg)
(b)
ρxx (mΩ cm)
(c)
T=2 K
20 K
50 K
100 K
200 K
250 K
B=14 T
(d)

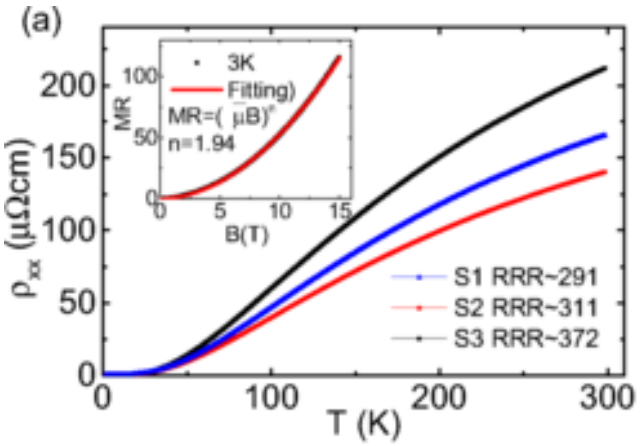

(a)
2 K
5 K
8 K
10K
15K
20K
30K
50K
70K
90K
B//b-axis
ρ(T)/ρ(0)
B(T)
(b)
dR/dB(10⁻⁴Ω/T)
0.75
1.75
2.75
3.75
n=4.75
1/ B*(2K)
1/B(T⁻¹)

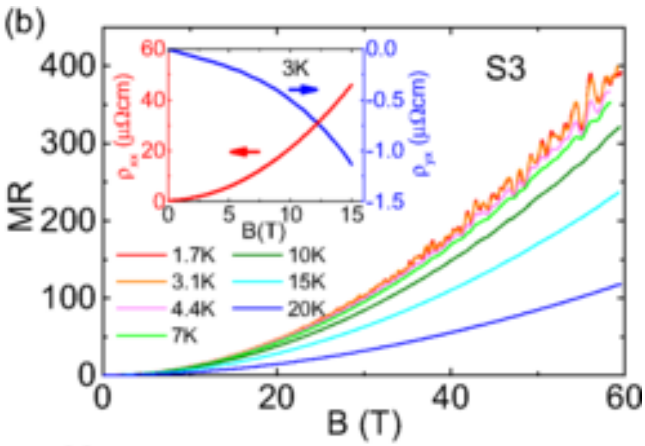

(a)
8.0 K
1.8 K
U (mV)
I (mA)
(b)
1.8 K
7.0 K
G/G∞
U (mV)

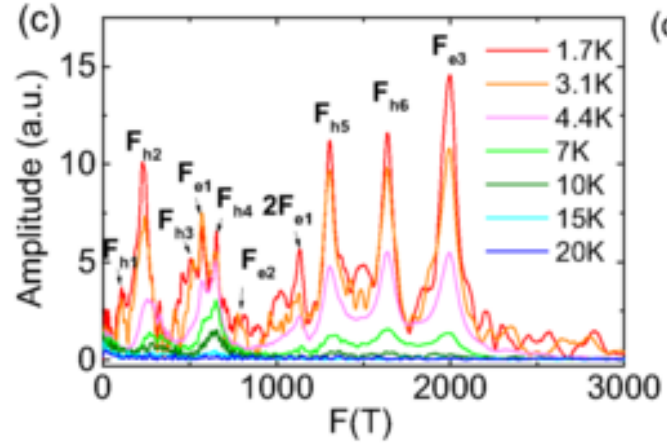

(a)
2 K
3 K
4 K
5 K
6 K
7 K
8 K
10K
20K
R_xy (Ω)
B (T)
(b)
n=1
2
3
4
5
ΔR_xy (Ω)
1/B(T^-1)
(c)
LL n =2
m* =0.026 m_e
ΔR_xy/ΔR_xy(2K)
T(K)
(d)
Valley
Peak
Linear fitting
γ = - 0.18
n
1/B(T^-1)
(a1)
B ⊥ I
ρ_xx (mΩ – cm)
T (K)
(a2)
B ⊥ I
MR % (10^4)
B (T)
(b1)
B ∥ I
ρ_xx (mΩ – cm)
T (K)
(b2)
MR % (10^4%)
B (T)

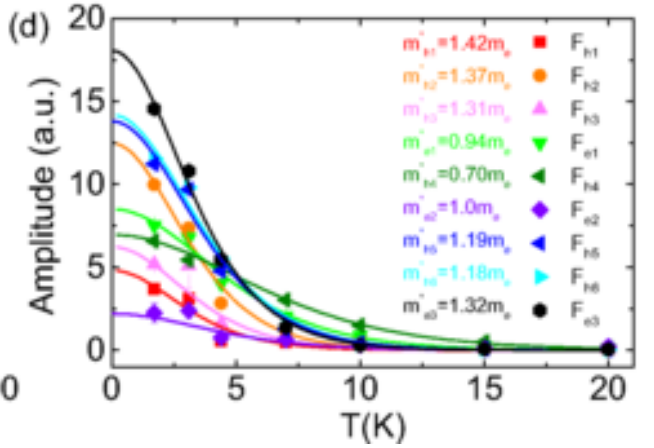

(a)
2.5K
3.5K
5 K
6.5K
8 K
10 K
30K
50K
75K
NbAs2
R (×10-2 Ω)
H (T)

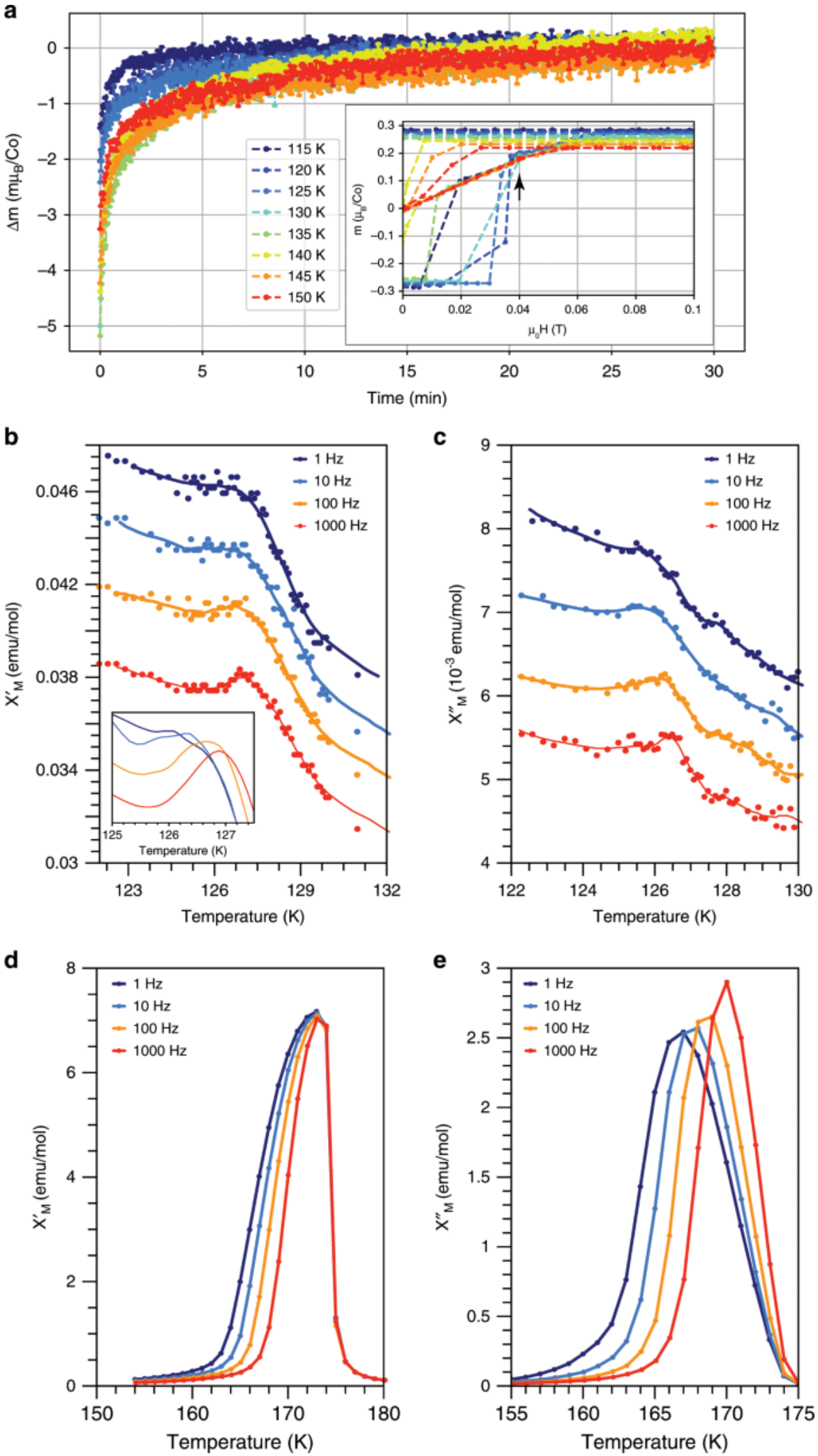

(b)
2.5K
3.5K
5 K
6.5K
8 K
10 K
20K
30K
50K
75K
TaAs2
R (×10-2 Ω)
H (T)

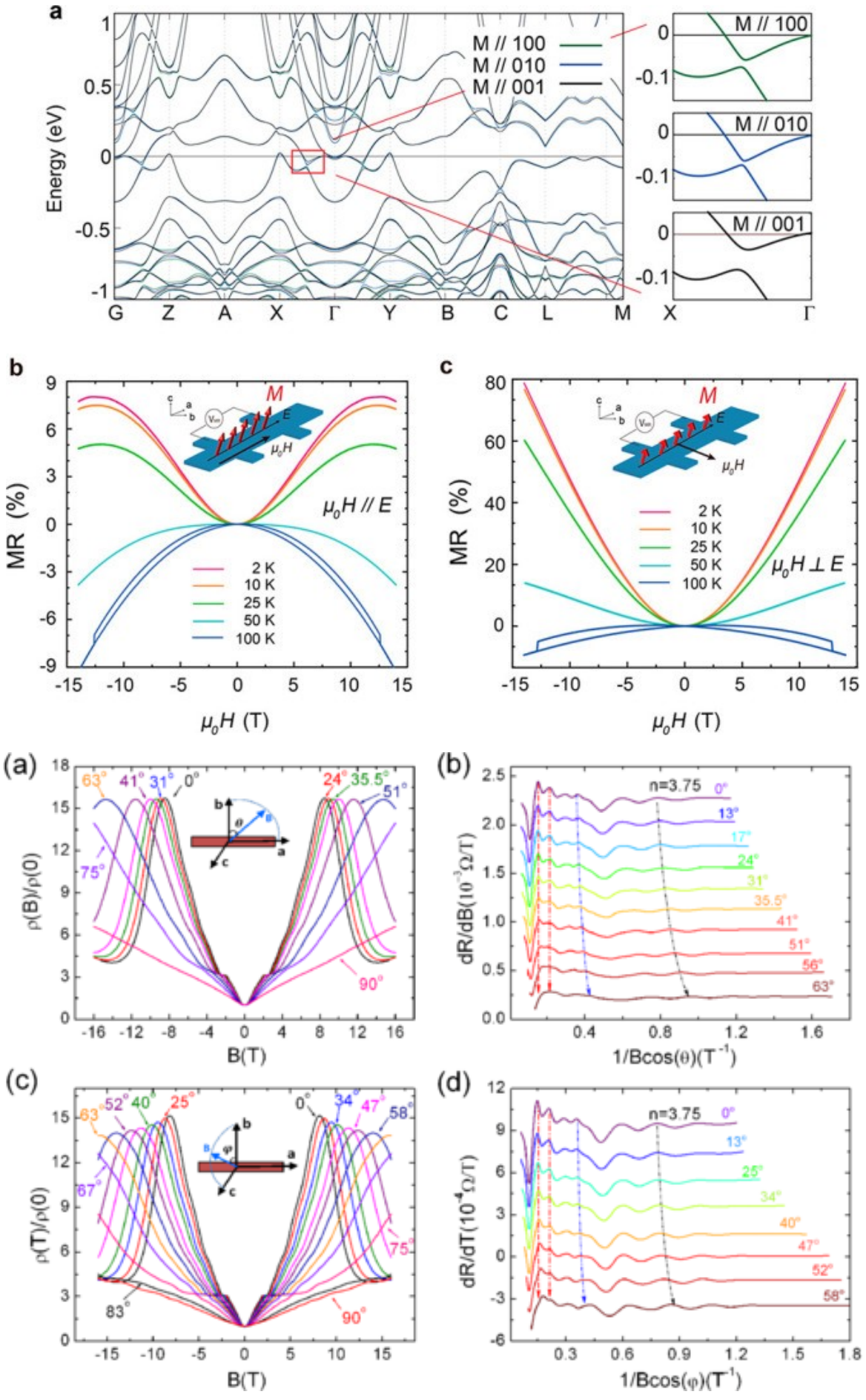

(a)
3K
Fitting)
MR=(μB)n
n=1.94
MR
B(T)
S1 RRR~291
S2 RRR~311
S3 RRR~372
ρxx (μΩcm)
T (K)

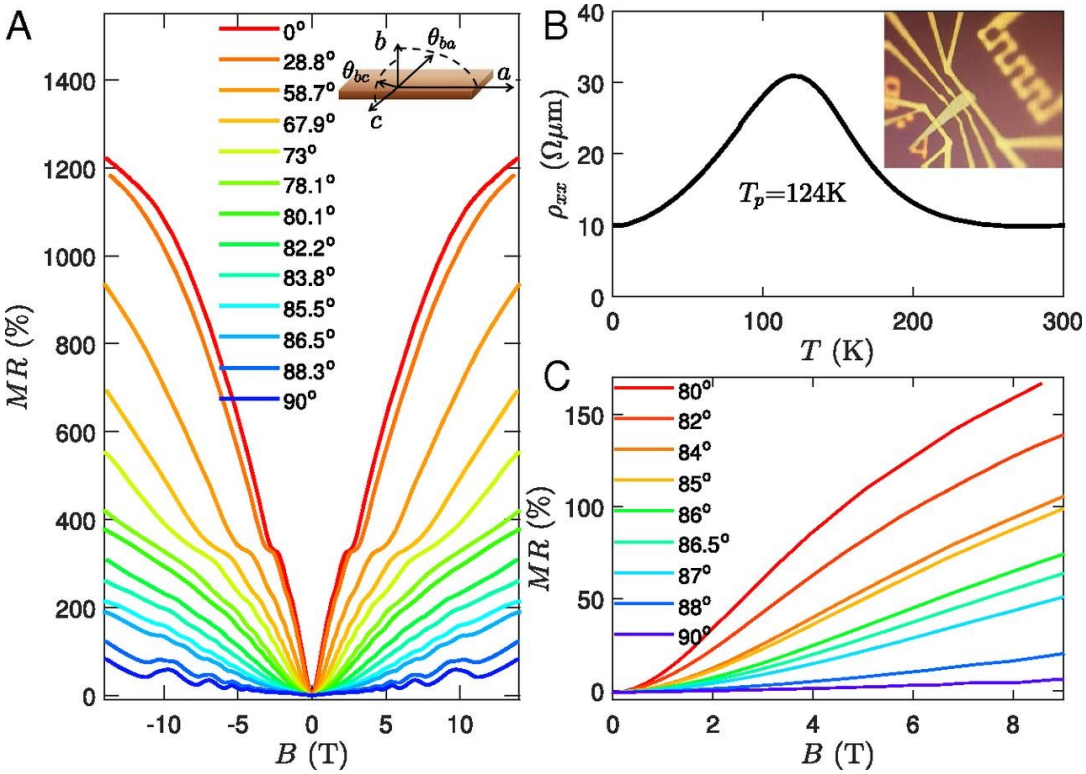

(b)
S3
3K
ρxx (μΩcm)
ρyx (μΩcm)
B(T)
1.7K
3.1K
4.4K
7K
10K
15K
20K
MR
B (T)

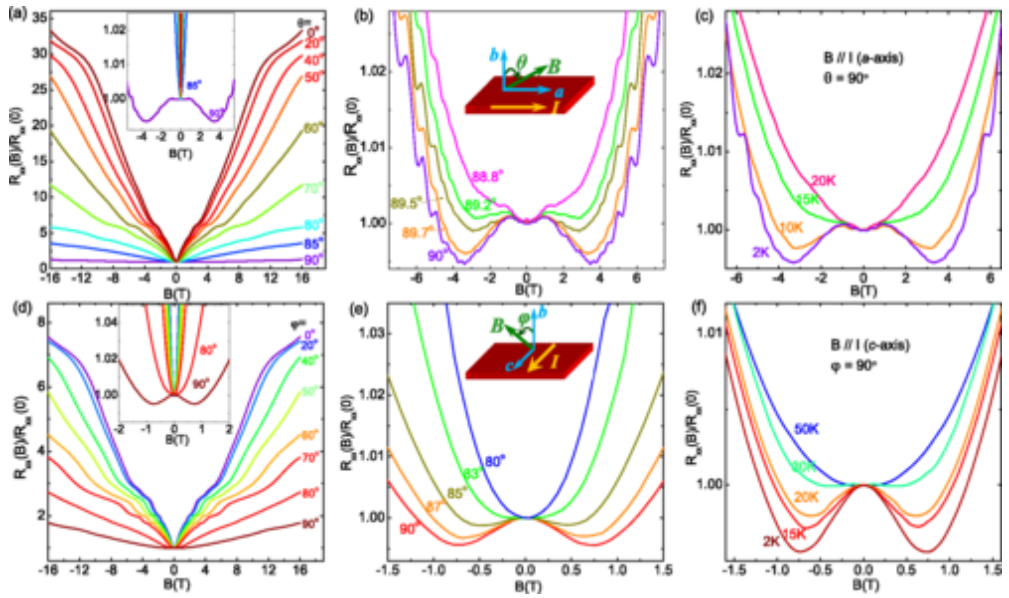

(c)
Fh1
Fh2
Fh3
Fe1
Fh4
2Fe1
Fe2
Fh5
Fh6
Fe3
1.7K
3.1K
4.4K
7K
10K
15K
20K
Amplitude (a.u.)
F(T)

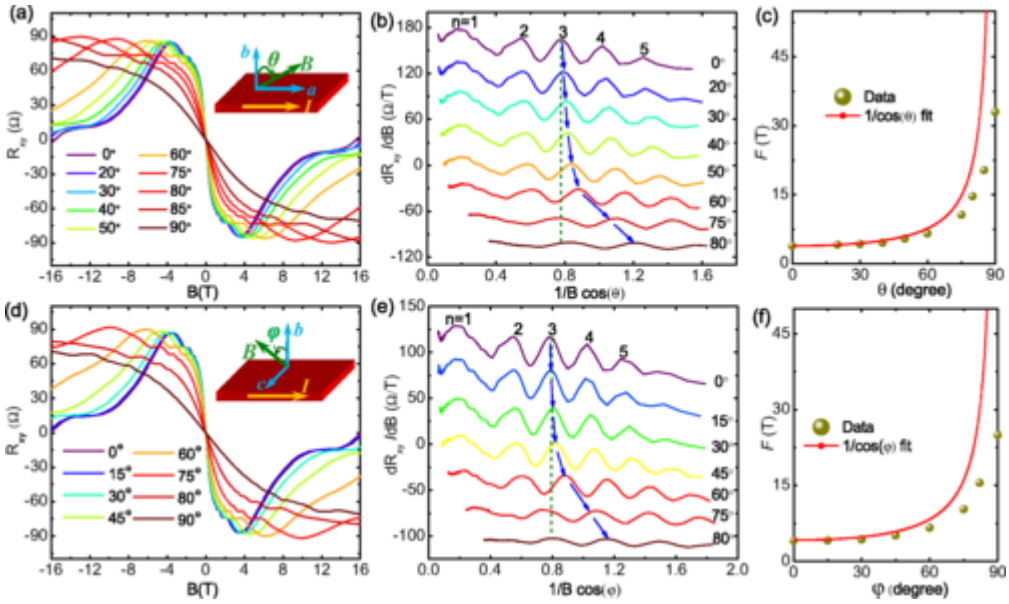

(d)
m*h1=1.42me
m*h2=1.37me
m*h3=1.31me
m*e1=0.94me
m*h4=0.70me
m*e2=1.0me
m*h5=1.19me
m*h6=1.18me
m*e3=1.32me
Fh1
Fh2
Fh3
Fe1
Fh4
Fe2
Fh5
Fh6
Fe3
Amplitude (a.u.)
T(K)

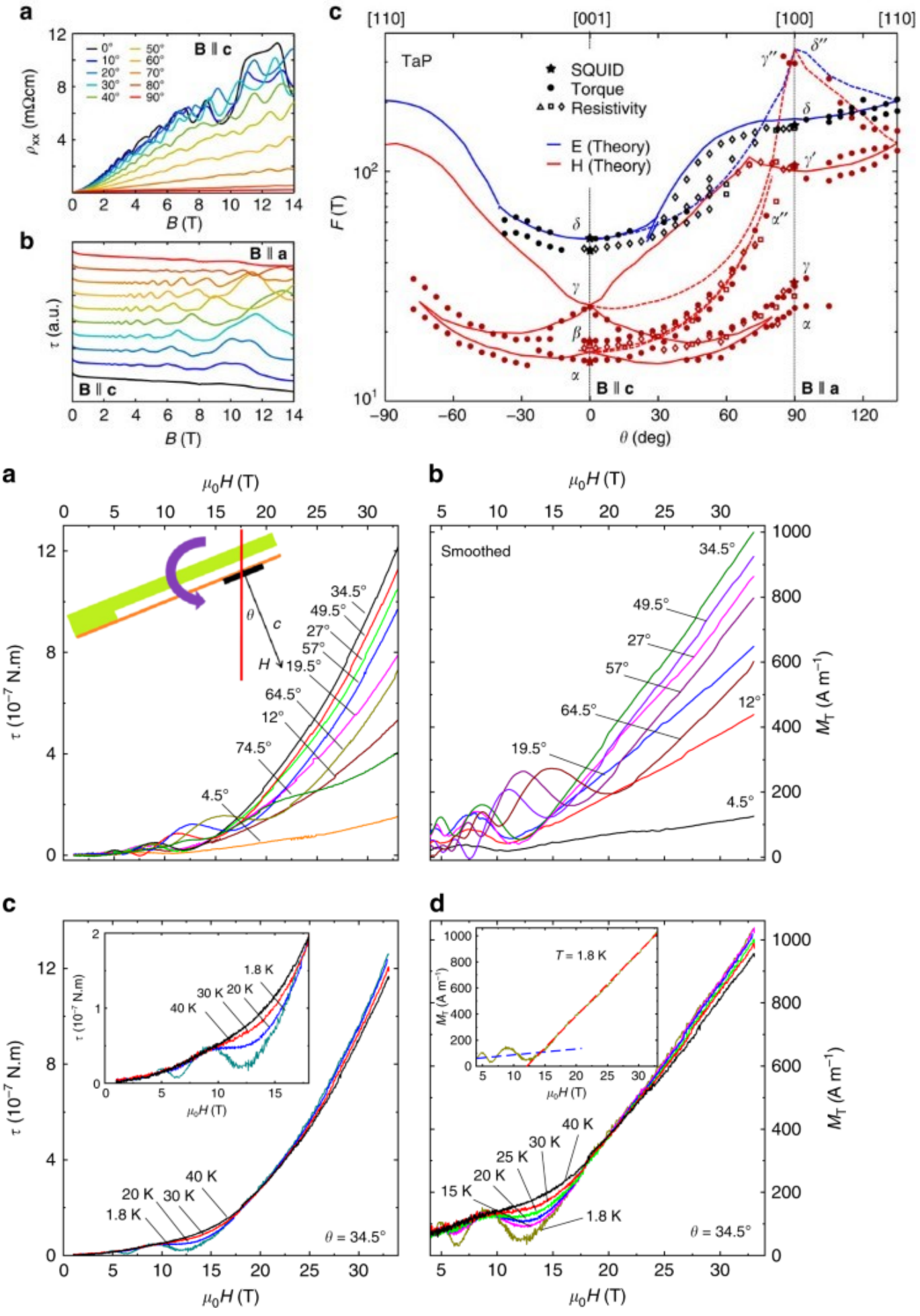

a
Δm (mμB/Co)
Time (min)
115 K
120 K
125 K
130 K
135 K
140 K
145 K
150 K
m (μB/Co)
μ0H (T)
b
X′M (emu/mol)
1 Hz
10 Hz
100 Hz
1000 Hz
Temperature (K)
c
X″M (10-3 emu/mol)
1 Hz
10 Hz
100 Hz
1000 Hz
Temperature (K)
d
X′M (emu/mol)
1 Hz
10 Hz
100 Hz
1000 Hz
Temperature (K)
e
X″M (emu/mol)
1 Hz
10 Hz
100 Hz
1000 Hz
Temperature (K)

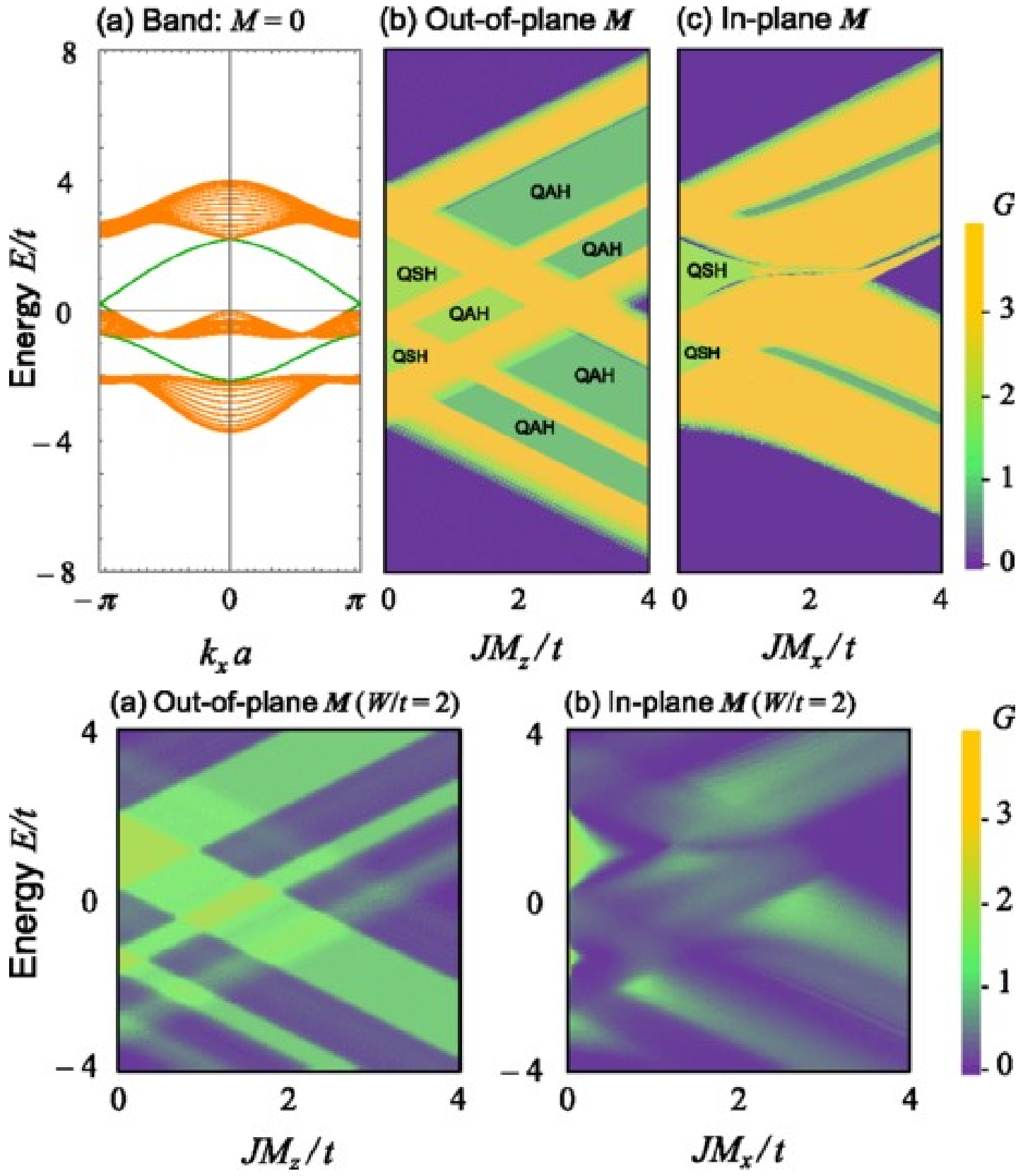

a
Energy (eV)
M // 100
M // 010
M // 001
G Z A X Γ Y B C L M
X Γ
b
MR (%)
μ0H // E
2 K
10 K
25 K
50 K
100 K
μ0H (T)
c
MR (%)
μ0H ⊥ E
μ0H (T)
(a)
ρ(B)/ρ(0)
B(T)
(b)
dR/dB(10^-3 Ω/T)
n=3.75
1/Bcos(θ)(T^-1)
(c)
ρ(T)/ρ(0)
B(T)
(d)
dR/dT(10^-4 Ω/T)
n=3.75
1/Bcos(φ)(T^-1)

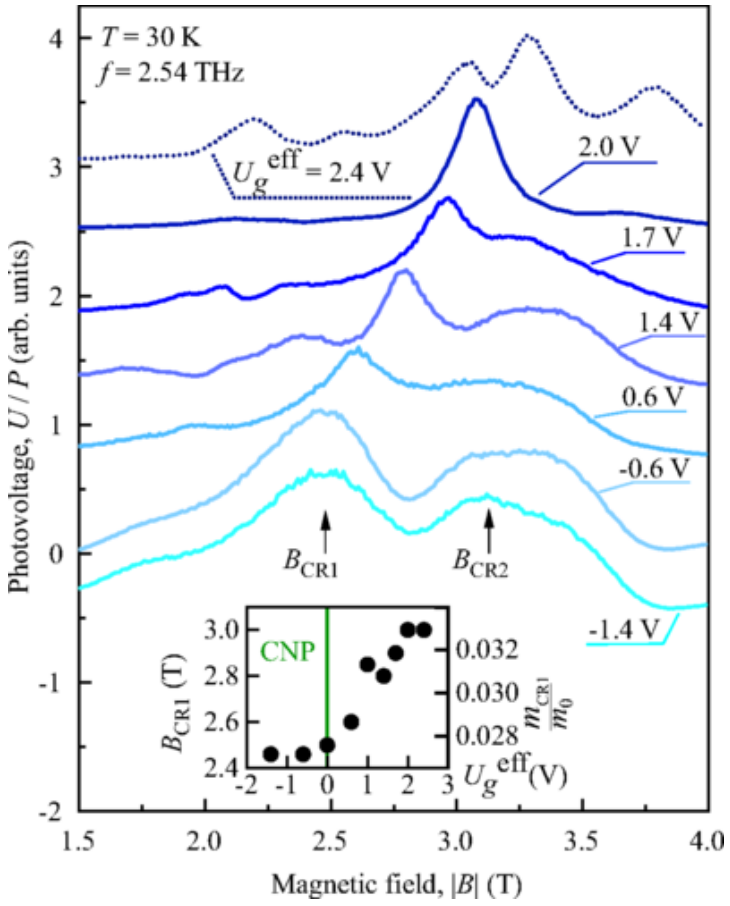

A
B
C
MR (%)
B (T)
ρxx (Ωμm)
T (K)
Tp=124K
0°
28.8°
58.7°
67.9°
73°
78.1°
80.1°
82.2°
83.8°
85.5°
86.5°
88.3°
90°
80°
82°
84°
85°
86°
86.5°
87°
88°
90°

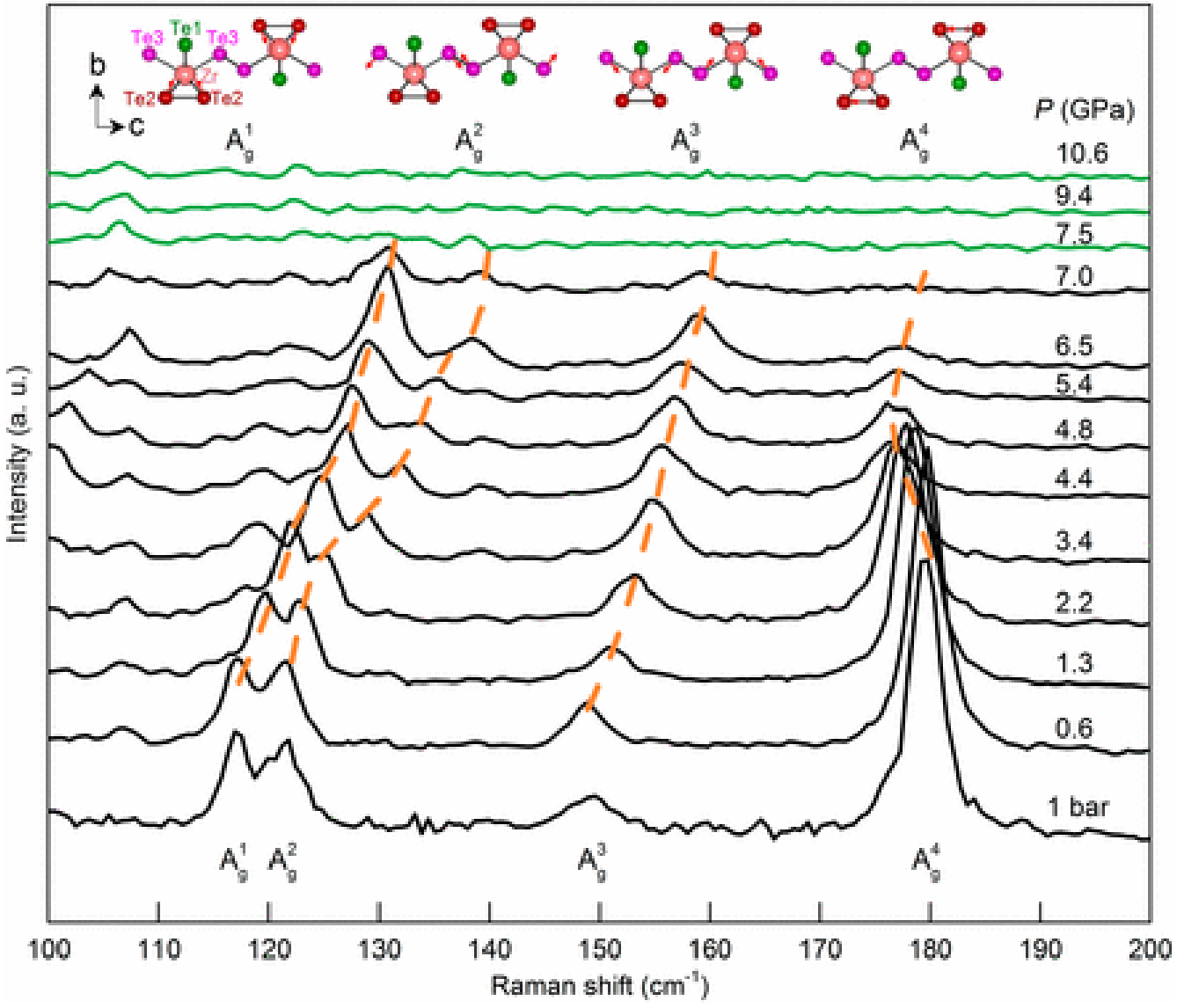

B // I (a-axis)
θ = 90°
B // I (c-axis)
φ = 90°
B(T)

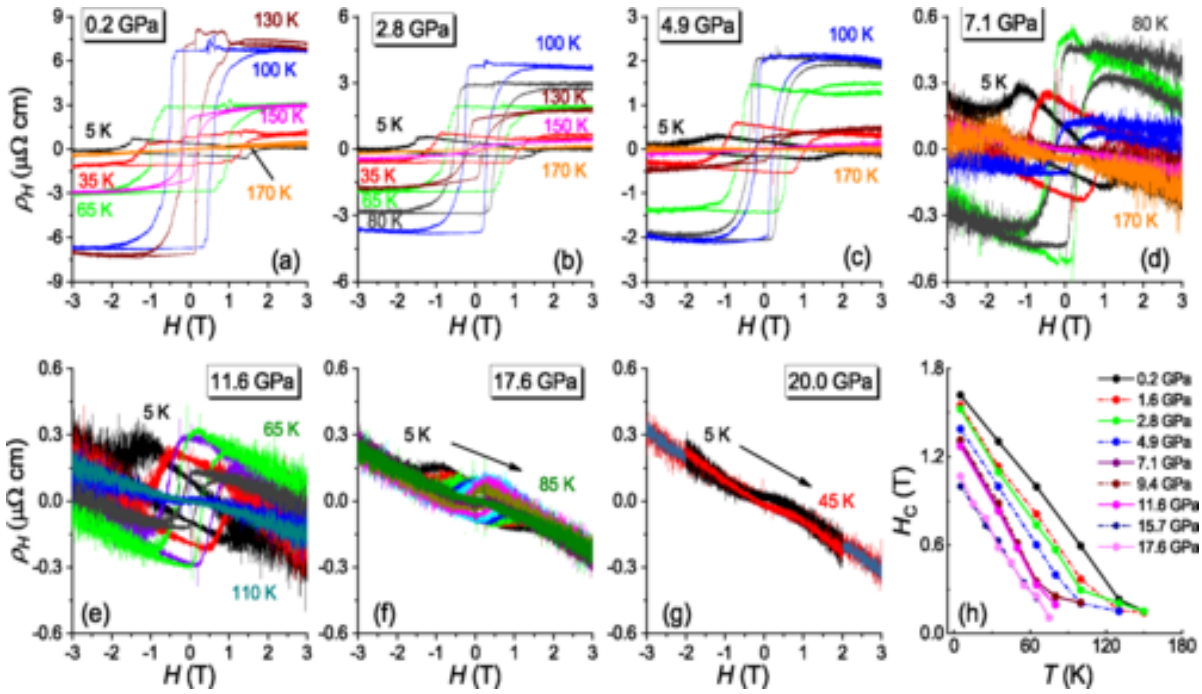

Data
1/cos(θ) fit
1/cos(φ) fit
θ (degree)
φ (degree)
F (T)
1/B cos(θ)
1/B cos(φ)
n=1

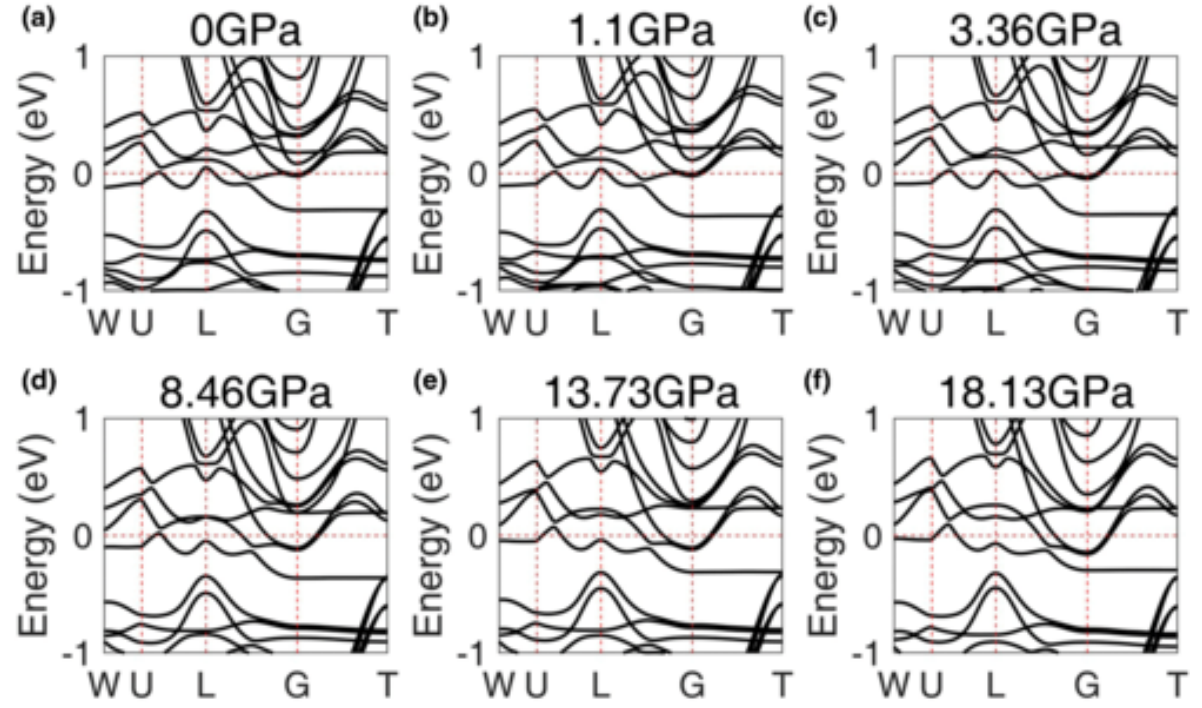

a
b
c
d
TaP
SQUID
Torque
Resistivity
E (Theory)
H (Theory)
B ∥ c
B ∥ a
[110]
[001]
[100]
[110]
F (T)
θ (deg)
ρxx (mΩcm)
τ (a.u.)
B (T)
μ0H (T)
τ (10−7 N.m)
MT (A m−1)
Smoothed
T = 1.8 K
θ = 34.5°

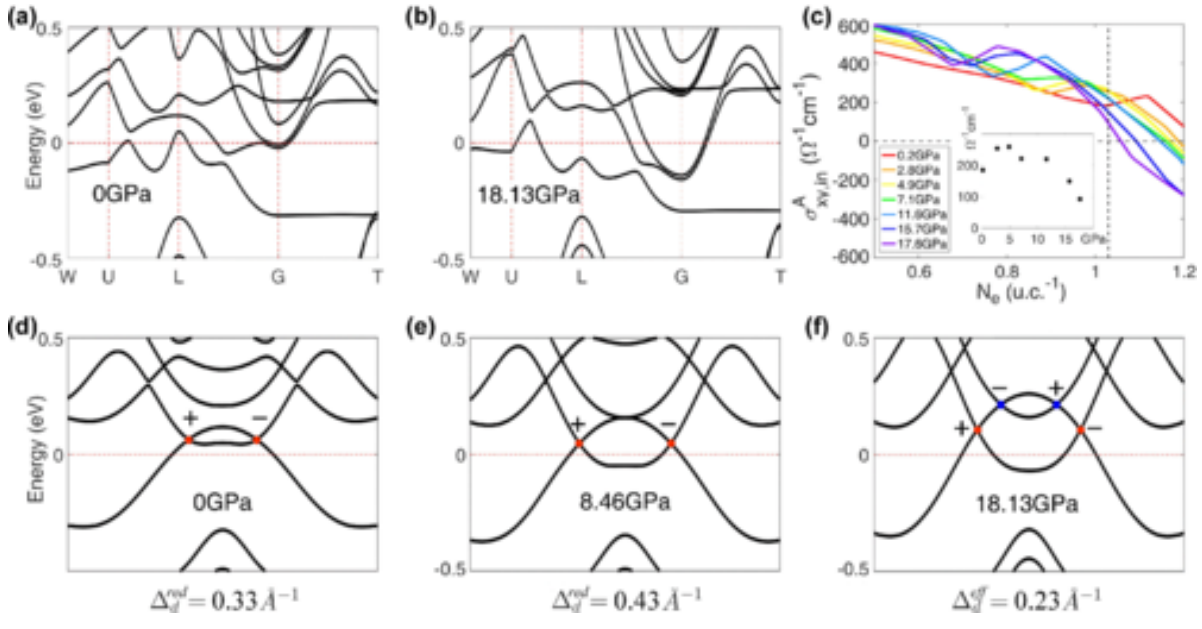

(a) Band: $M = 0$
(b) Out-of-plane M
(c) In-plane M
Energy E/t
8
4
0
−4
−8
$-\pi$
0
π
$k_x a$
QAH
QSH
QAH
QSH
QAH
QAH
QSH
QSH
0
2
4
JM_z/t
JM_x/t
G
3
2
1
0
(a) Out-of-plane M $(W/t = 2)$
(b) In-plane M $(W/t = 2)$
Energy E/t
4
0
−4
0
2
4
JM_z/t
JM_x/t
G
3
2
1
0

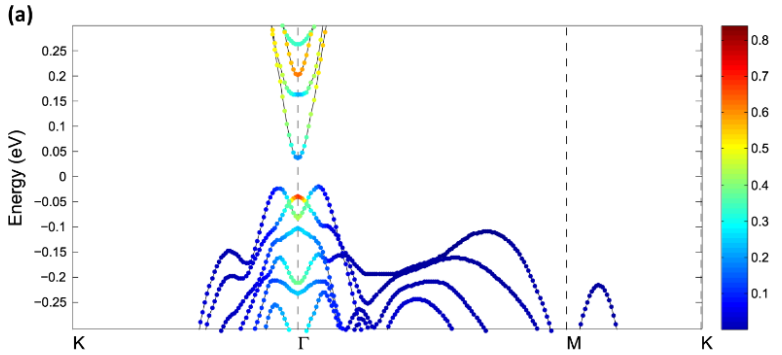

T = 30 K
f = 2.54 THz
2.0 V
1.7 V
1.4 V
0.6 V
-0.6 V
-1.4 V
Photovoltage, U / P (arb. units)
Magnetic field, |B| (T)
B_CR1
B_CR2
CNP
B_CR1 (T)
m_CR1 / m_0
U_g^eff (V)

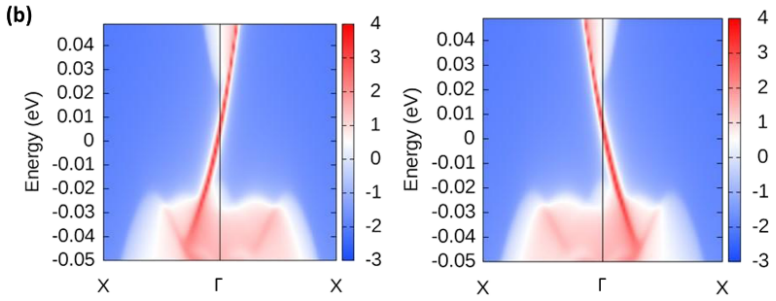

Te3
Te1
Te3
Zr
Te2
Te2
b
c
A_g^1
A_g^2
A_g^3
A_g^4
P (GPa)
10.6
9.4
7.5
7.0
6.5
5.4
4.8
4.4
3.4
2.2
1.3
0.6
1 bar
Intensity (a. u.)
Raman shift (cm^-1)

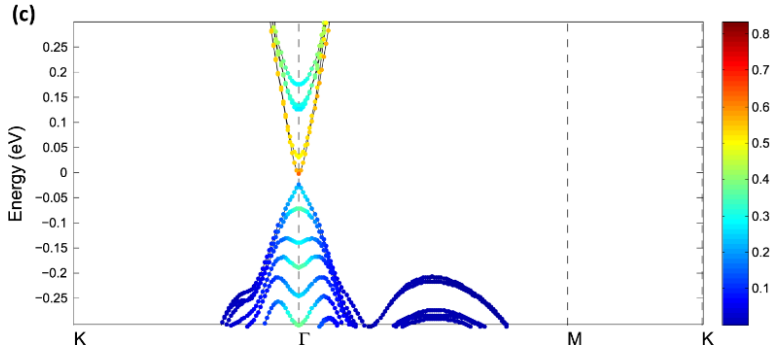

0.2 GPa
2.8 GPa
4.9 GPa
7.1 GPa
11.6 GPa
17.6 GPa
20.0 GPa
ρ_H (μΩ cm)
H (T)
T (K)
H_C (T)
(a)
(b)
(c)
(d)
(e)
(f)
(g)
(h)
0.2 GPa
1.6 GPa
2.8 GPa
4.9 GPa
7.1 GPa
9.4 GPa
11.6 GPa
15.7 GPa
17.6 GPa

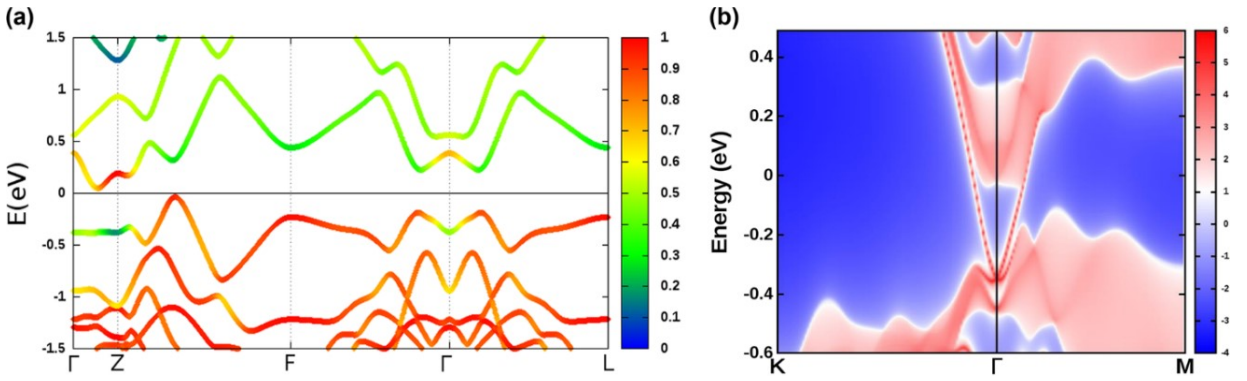

0GPa
1.1GPa
3.36GPa
8.46GPa
13.73GPa
18.13GPa
Energy (eV)
W U L G T

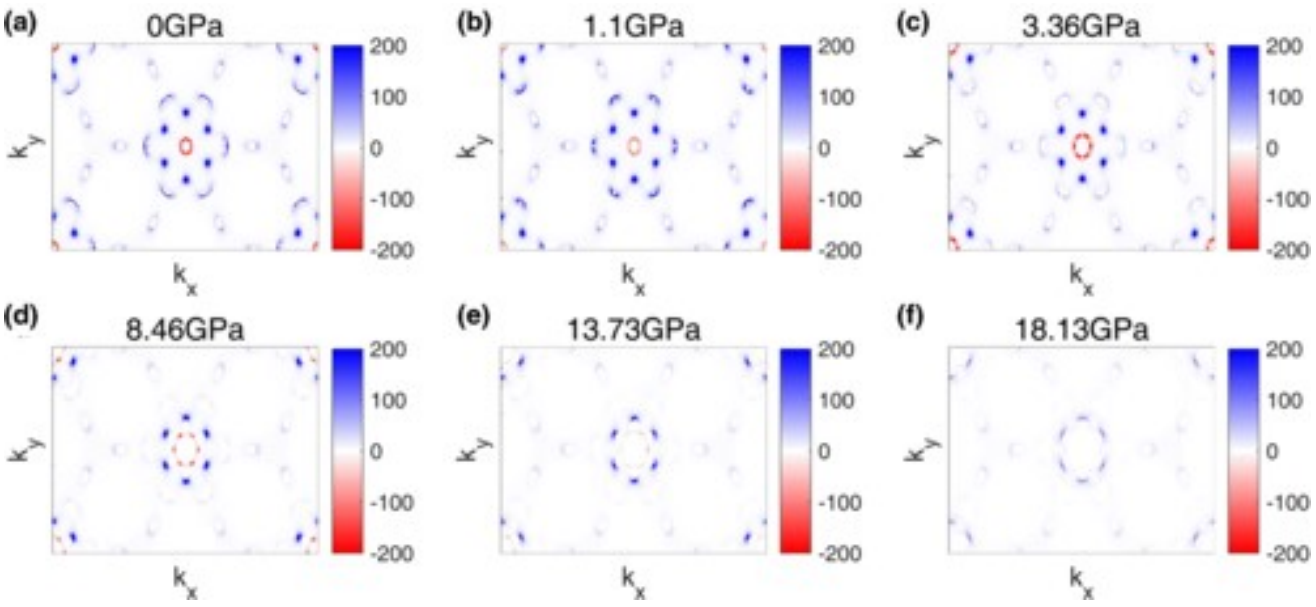

0GPa
18.13GPa
8.46GPa
$\sigma^A_{xy,in}$ (Ω^{-1}cm^{-1})
N_e (u.c.$^{-1}$)
$\Delta_g^{ind} = 0.33\,\AA^{-1}$
$\Delta_g^{ind} = 0.43\,\AA^{-1}$
$\Delta_g^{eff} = 0.23\,\AA^{-1}$

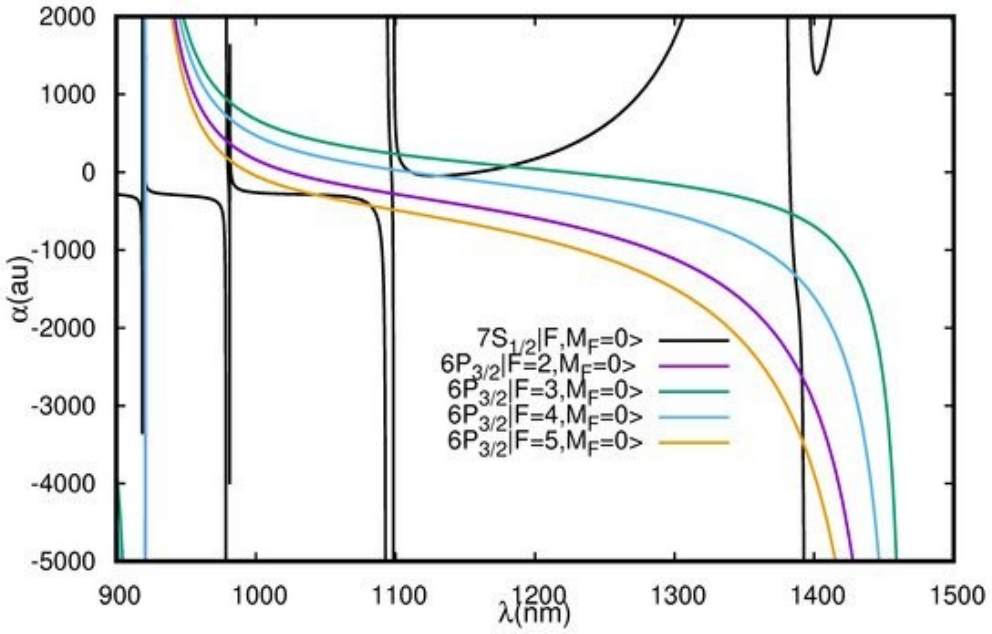

(a)
Energy (eV)
K
Γ
M
K

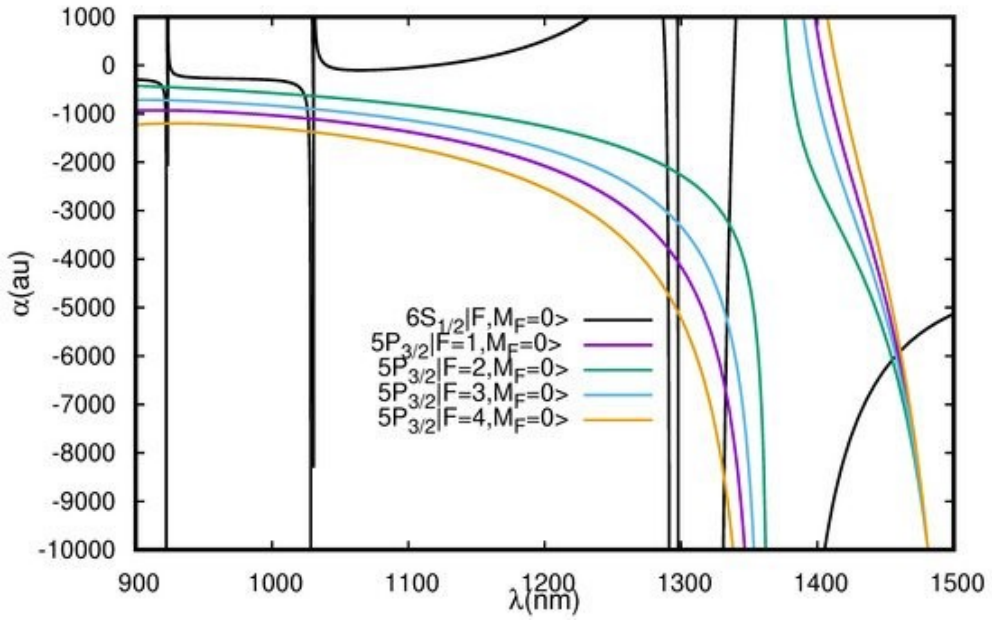

(b)
Energy (eV)
X
Γ
X
Energy (eV)
X
Γ
X

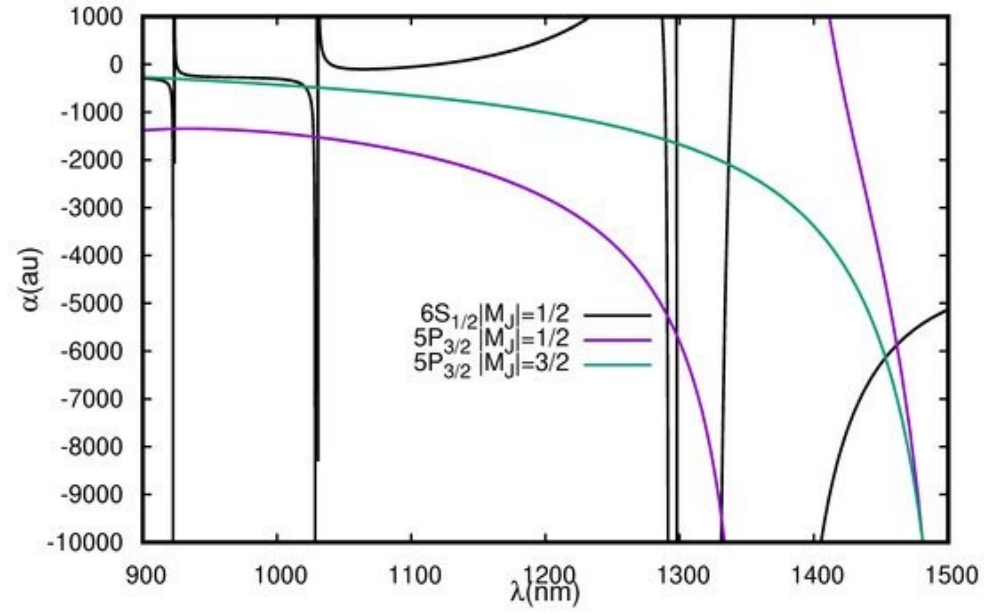

(c)
Energy (eV)
K
Γ
M
K

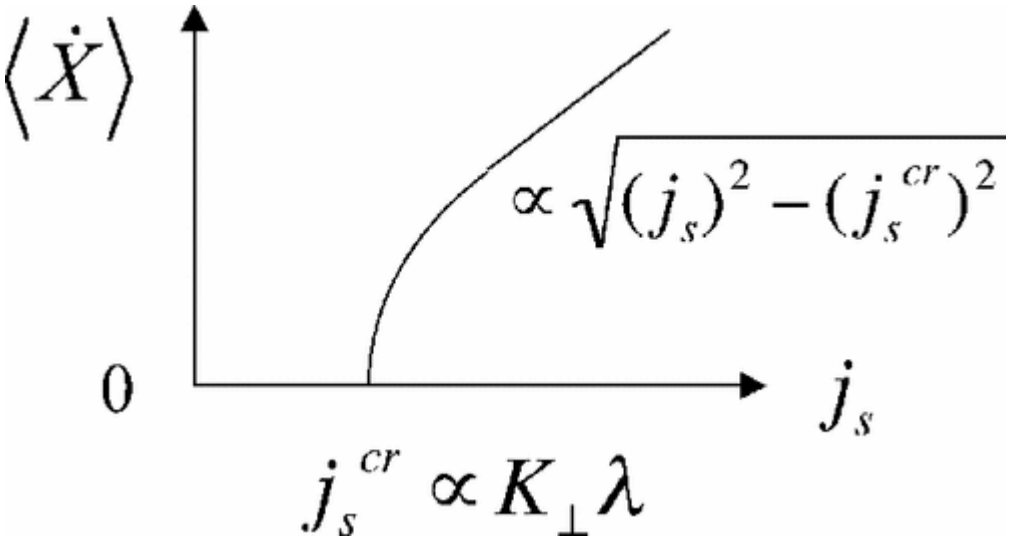

(a)
E(eV)
Γ
Z
F
Γ
L
(b)
Energy (eV)
K
Γ
M

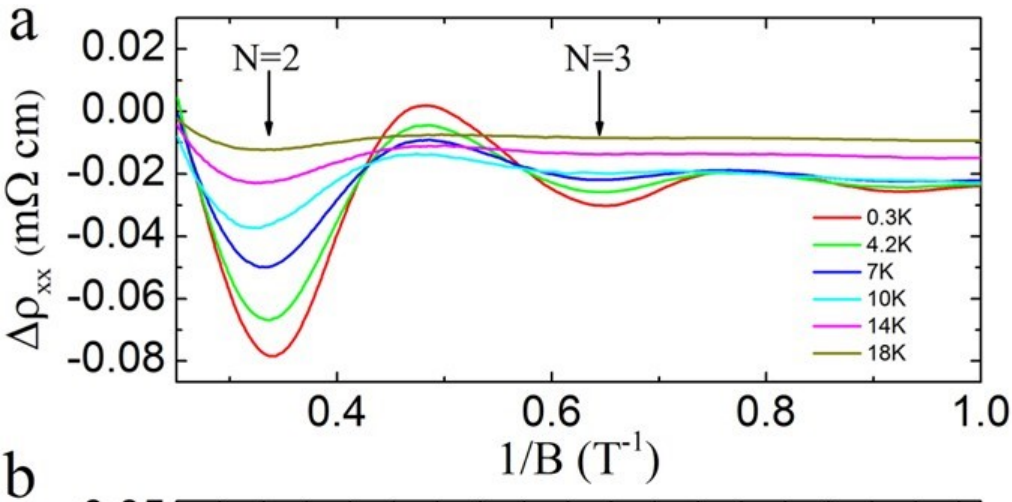

(a) 0GPa
(b) 1.1GPa
(c) 3.36GPa
(d) 8.46GPa
(e) 13.73GPa
(f) 18.13GPa
k_y
k_x

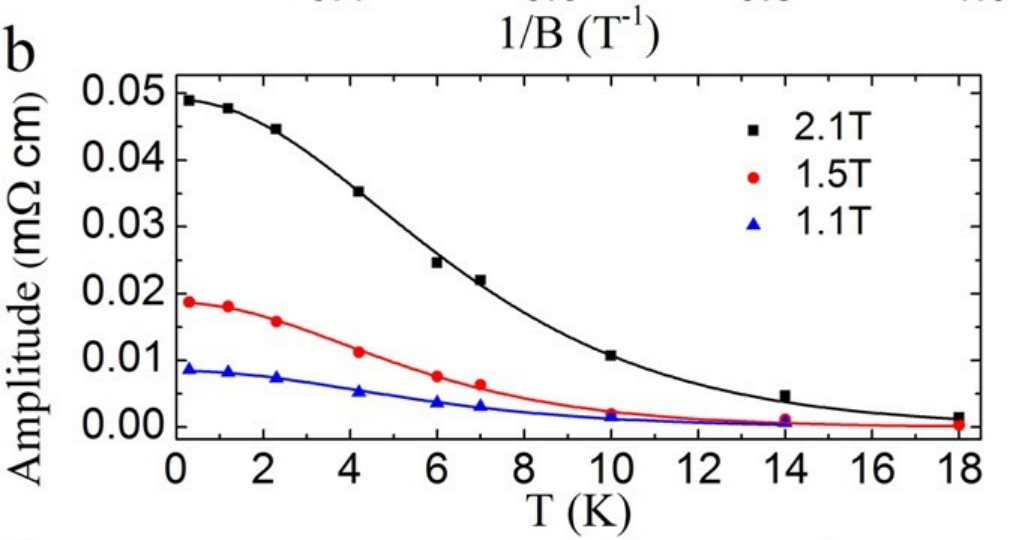

2000
1000
0
-1000
-2000
-3000
-4000
-5000
α(au)
900
1000
1100
1200
1300
1400
1500
λ(nm)
7S1/2|F,MF=0>
6P3/2|F=2,MF=0>
6P3/2|F=3,MF=0>
6P3/2|F=4,MF=0>
6P3/2|F=5,MF=0>

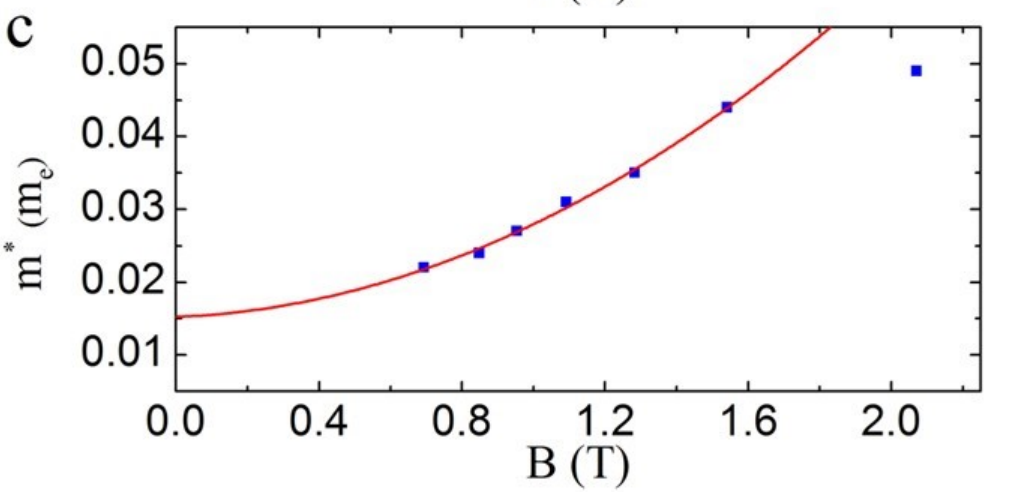

1000
0
-1000
-2000
-3000
-4000
-5000
-6000
-7000
-8000
-9000
-10000
α(au)
900
1000
1100
1200
1300
1400
1500
λ(nm)
6S1/2|F,MF=0>
5P3/2|F=1,MF=0>
5P3/2|F=2,MF=0>
5P3/2|F=3,MF=0>
5P3/2|F=4,MF=0>

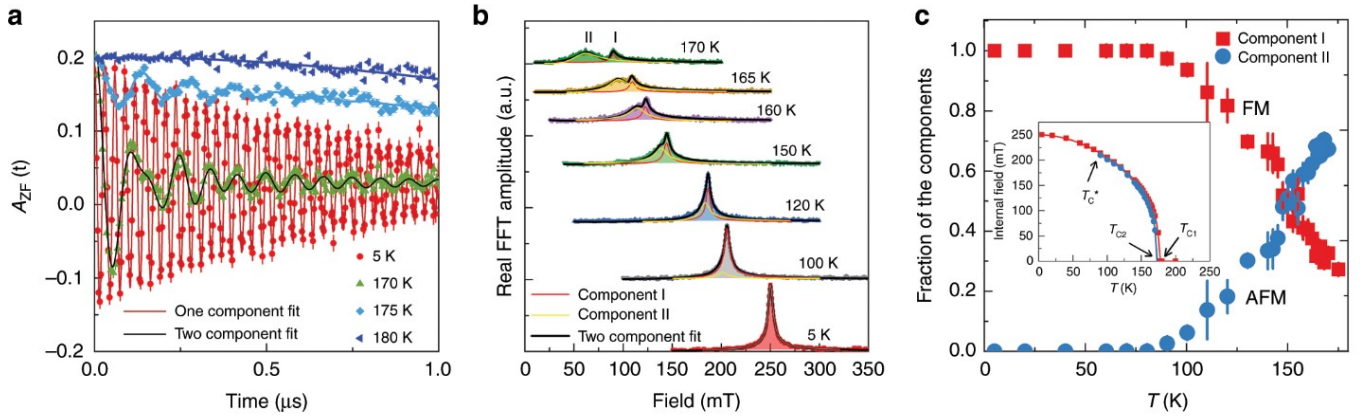

1000
0
-1000
-2000
-3000
-4000
-5000
-6000
-7000
-8000
-9000
-10000
α(au)
900
1000
1100
1200
1300
1400
1500
λ(nm)
6S1/2|MJ|=1/2
5P3/2 |MJ|=1/2
5P3/2 |MJ|=3/2

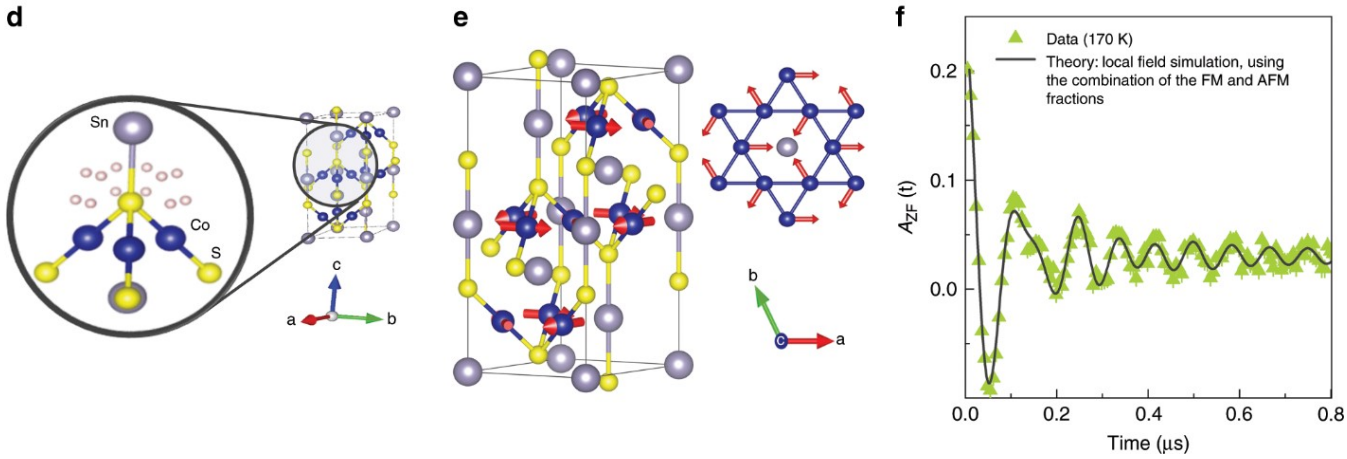

$\langle \dot{X} \rangle$
$\propto \sqrt{(j_s)^2 - (j_s^{cr})^2}$
0
j_s
$j_s^{cr} \propto K_\perp \lambda$

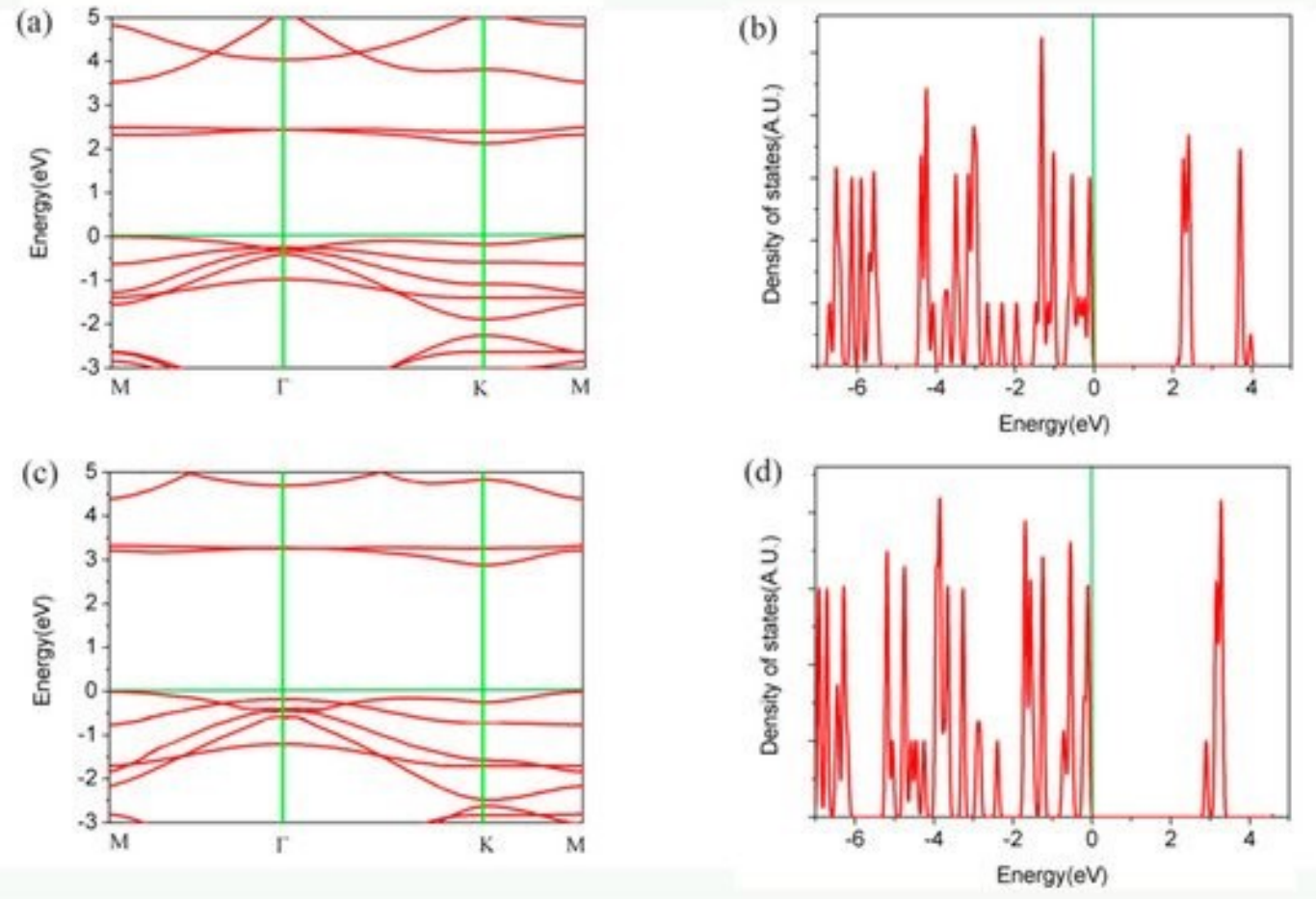

a
N=2
N=3
0.3K
4.2K
7K
10K
14K
18K
$\Delta\rho_{xx}$ (mΩ cm)
1/B (T^{-1})

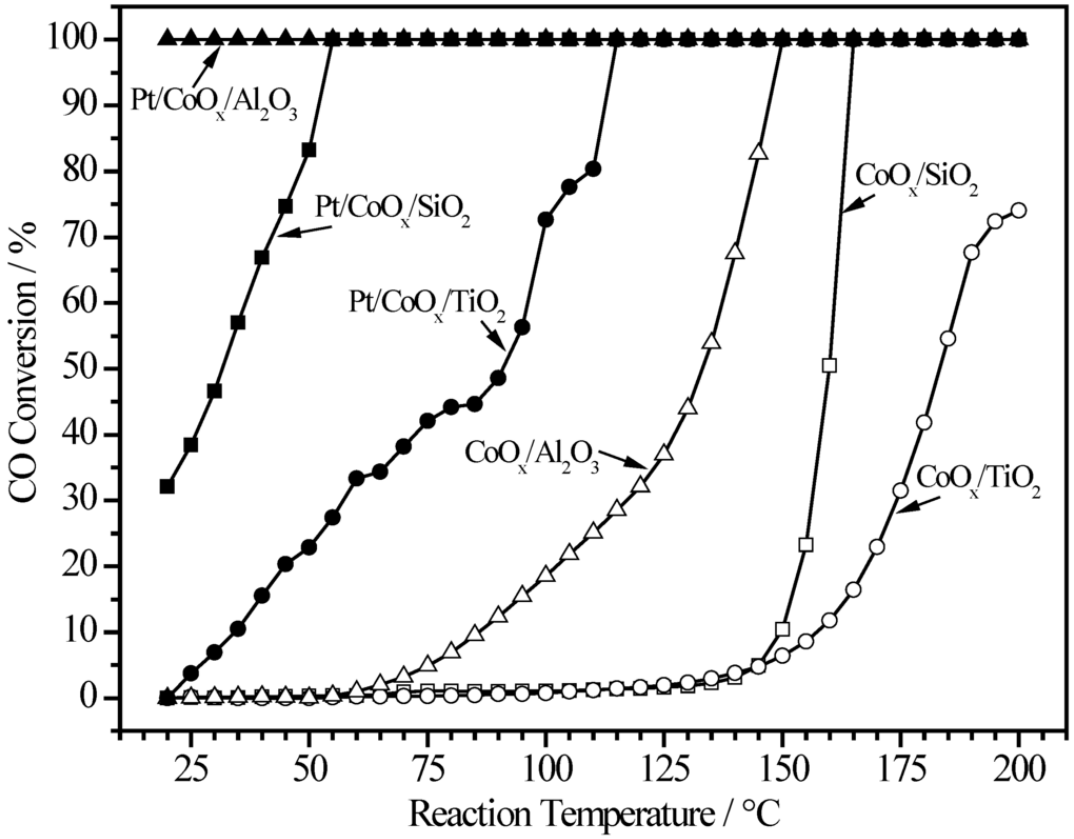

b
2.1T
1.5T
1.1T
Amplitude (mΩ cm)
T (K)

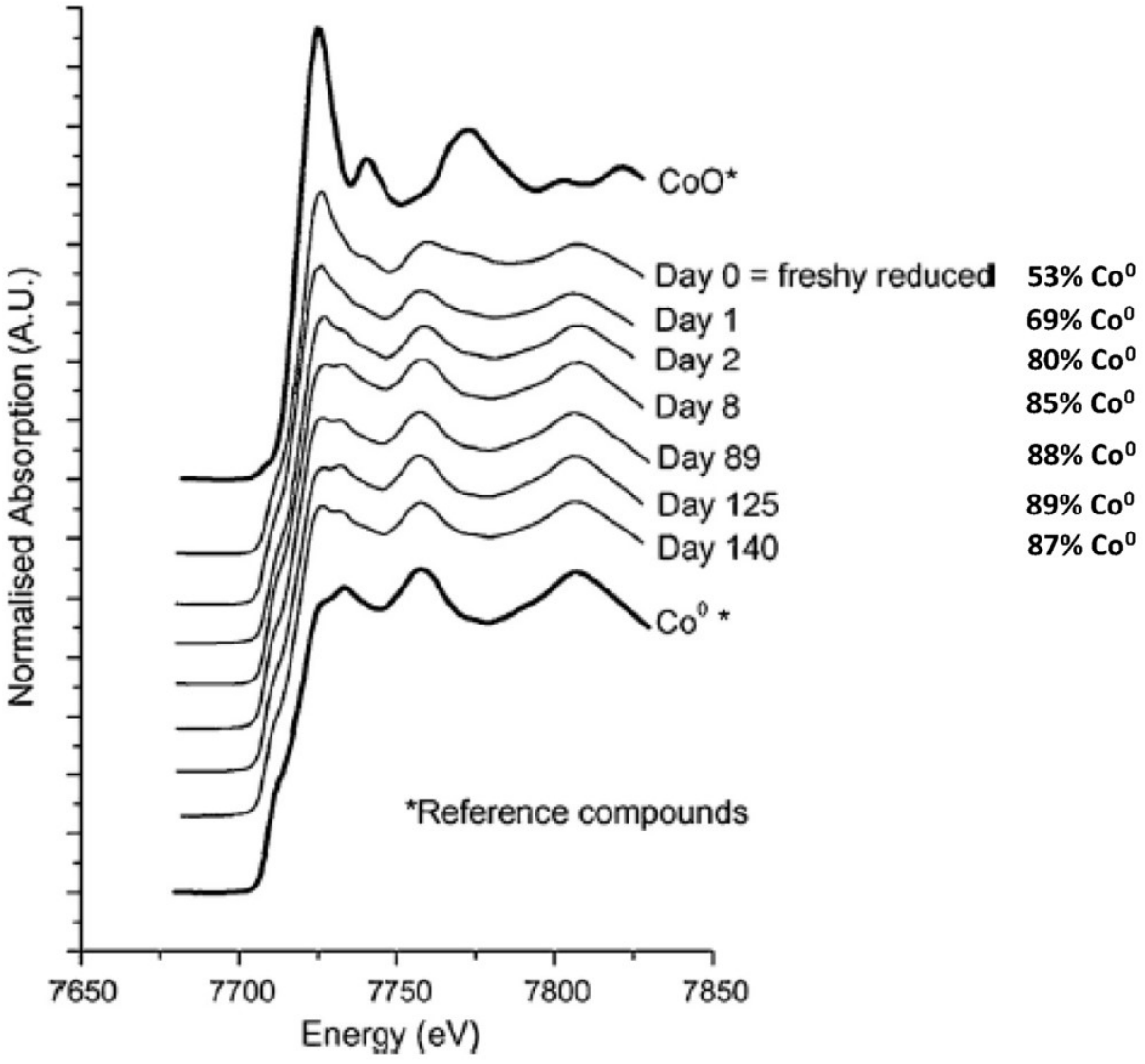

c
m^* (m_e)
B (T)

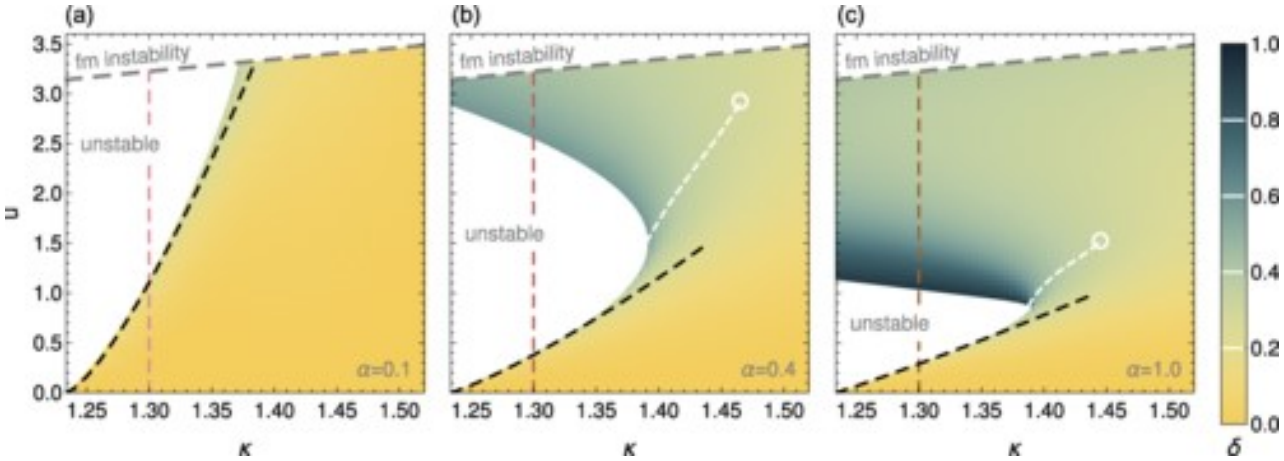

a
A_{ZF} (t)
Time (μs)
One component fit
Two component fit
5 K
170 K
175 K
180 K
b
Real FFT amplitude (a.u.)
Field (mT)
II
I
170 K
165 K
160 K
150 K
120 K
100 K
5 K
Component I
Component II
Two component fit
c
Fraction of the components
T (K)
Component I
Component II
FM
AFM
Internal field (mT)
T_C^*
T_{C2}
T_{C1}

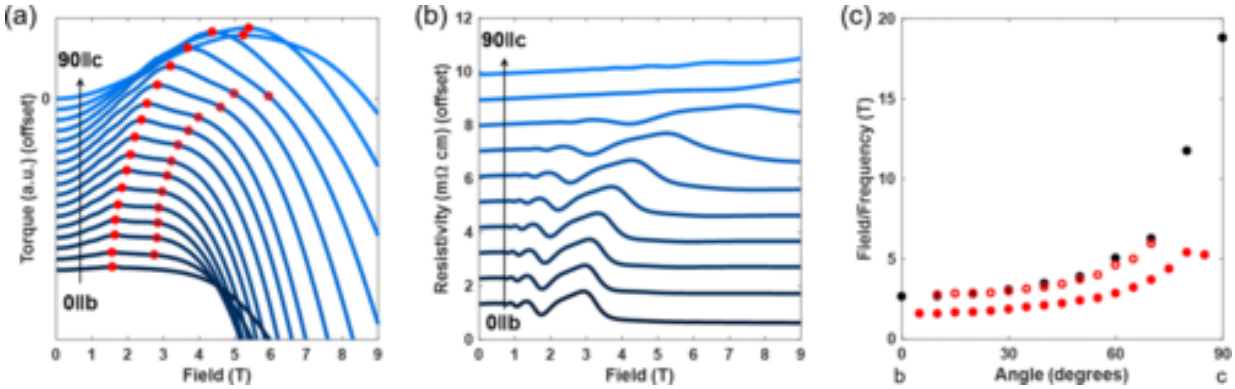

d
Sn
Co
S
c
a
b
e
b
c
a
f
Data (170 K)
Theory: local field simulation, using the combination of the FM and AFM fractions
A_{ZF} (t)
Time (μs)

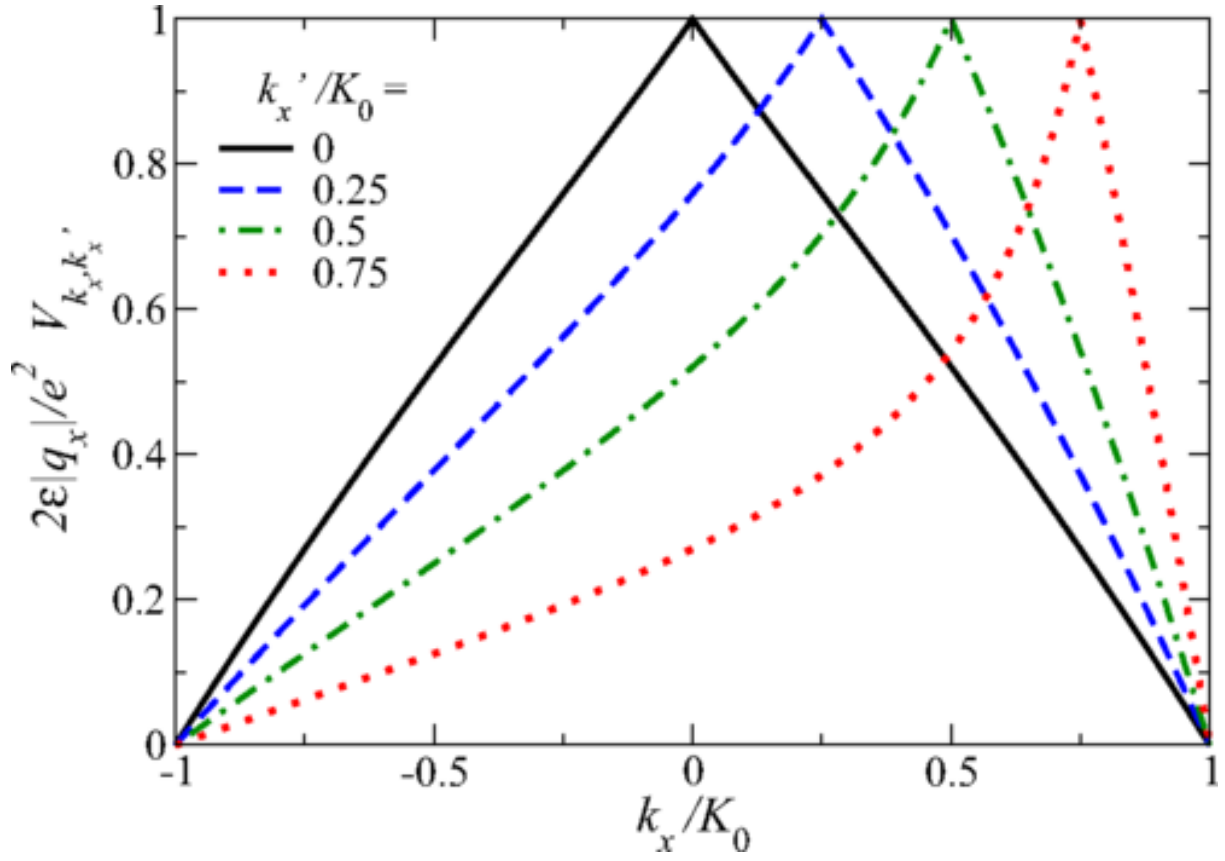

(a)
Energy(eV)
M
Γ
K
M
(b)
Density of states(A.U.)
Energy(eV)
(c)
Energy(eV)
M
Γ
K
M
(d)
Density of states(A.U.)
Energy(eV)

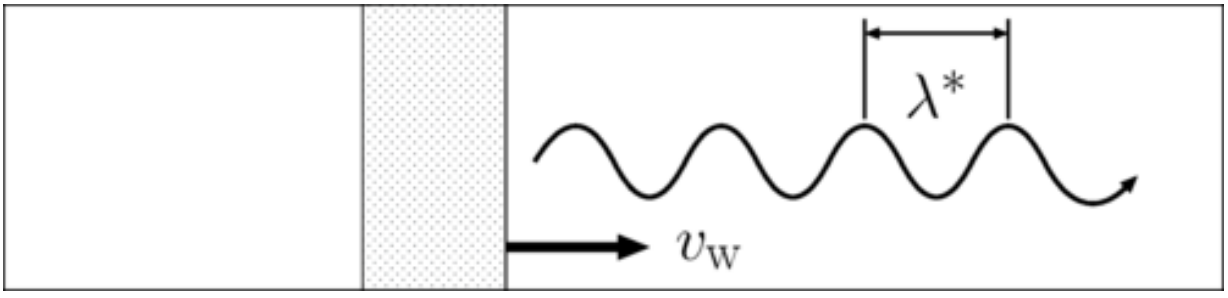

CO Conversion / %
Reaction Temperature / °C
Pt/CoO$_x$/Al$_2$O$_3$
Pt/CoO$_x$/SiO$_2$
Pt/CoO$_x$/TiO$_2$
CoO$_x$/Al$_2$O$_3$
CoO$_x$/SiO$_2$
CoO$_x$/TiO$_2$

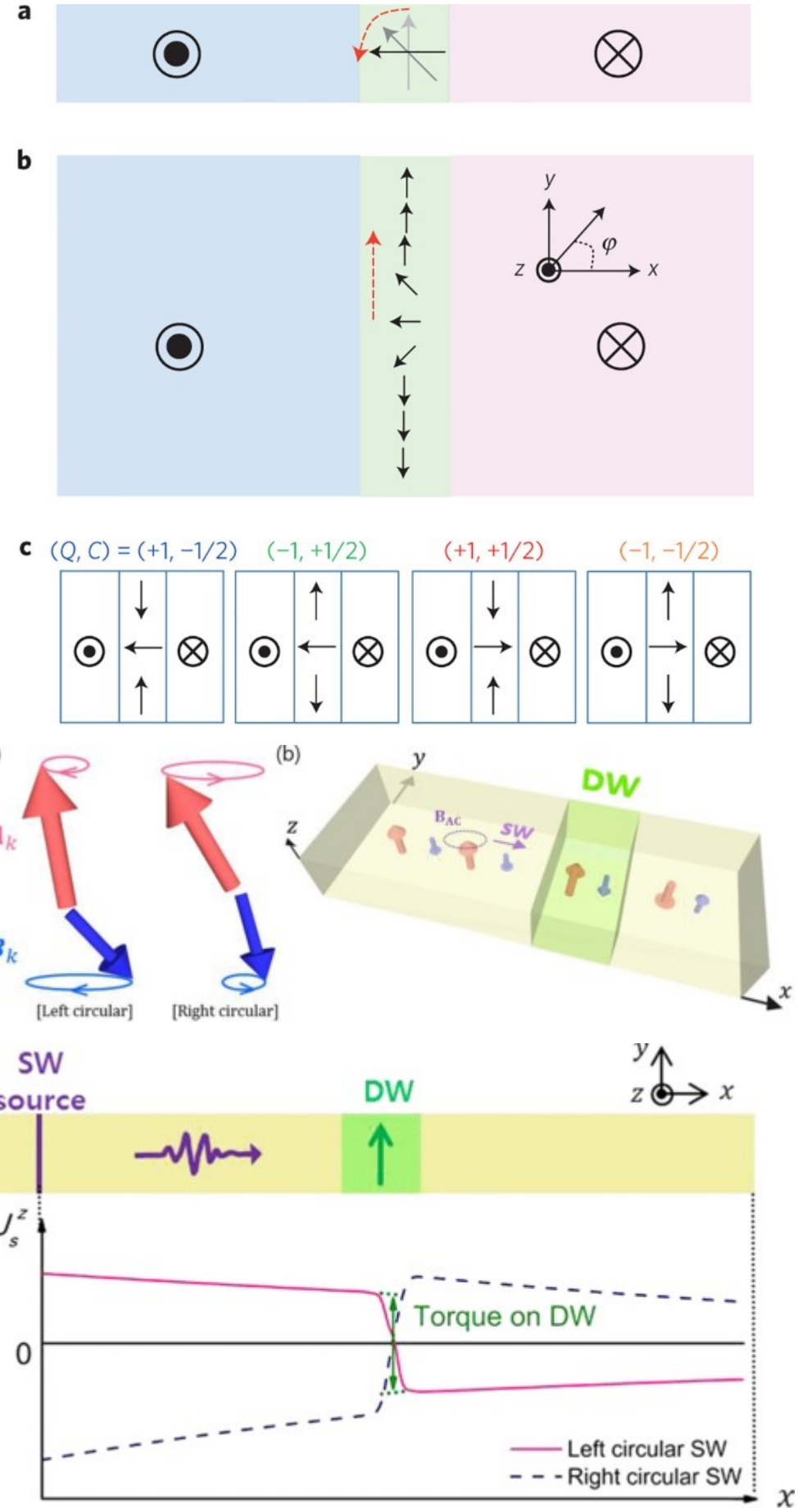

Normalised Absorption (A.U.)
Energy (eV)
CoO*
Day 0 = freshy reduced
Day 1
Day 2
Day 8
Day 89
Day 125
Day 140
Co^0 *
*Reference compounds
53% Co^0
69% Co^0
80% Co^0
85% Co^0
88% Co^0
89% Co^0
87% Co^0

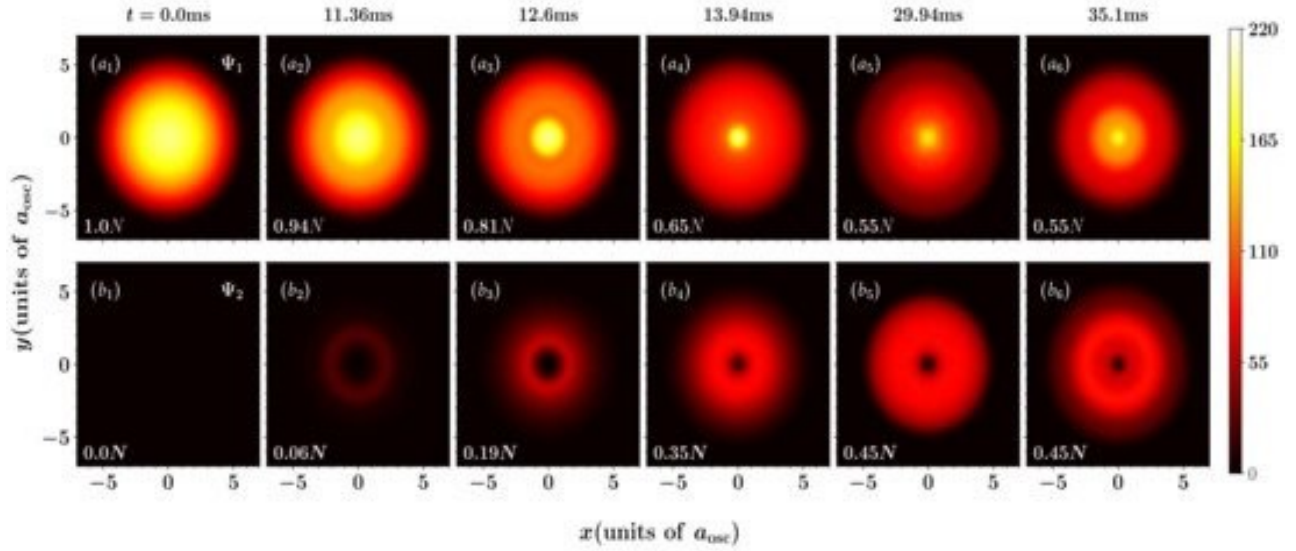

(a)
(b)
(c)
fm instability
unstable
α=0.1
α=0.4
α=1.0
u
κ
δ

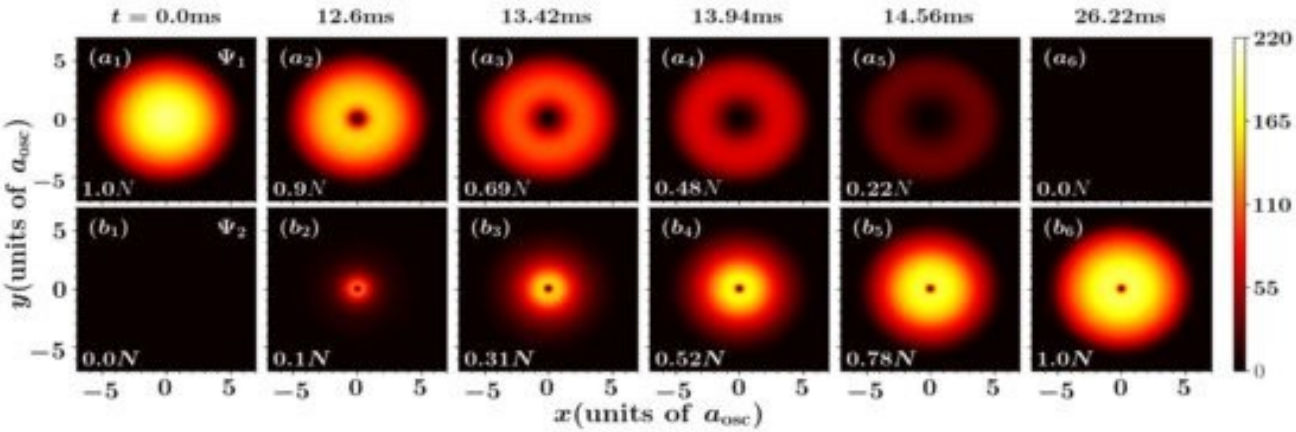

(a)
(b)
(c)
90llc
0llb
Torque (a.u.) (offset)
Resistivity (mΩ cm) (offset)
Field (T)
Field/Frequency (T)
Angle (degrees)
b
c

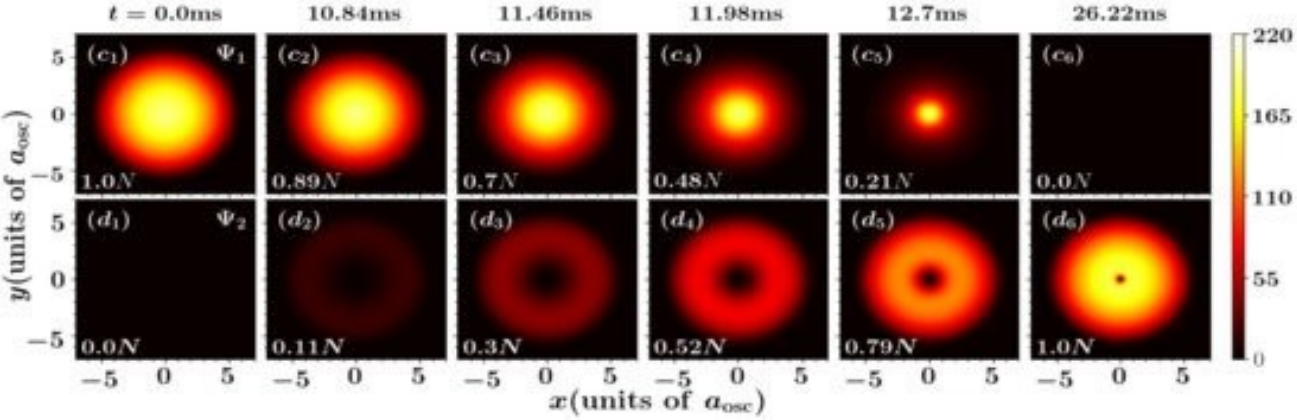

k_x'/K_0 =
0
0.25
0.5
0.75
$2\varepsilon|q_x|/e^2\ V_{k_x,k_x'}$
k_x/K_0

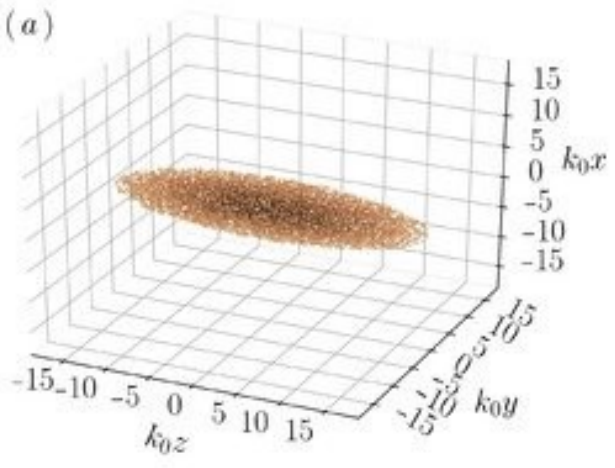

λ*
v_W

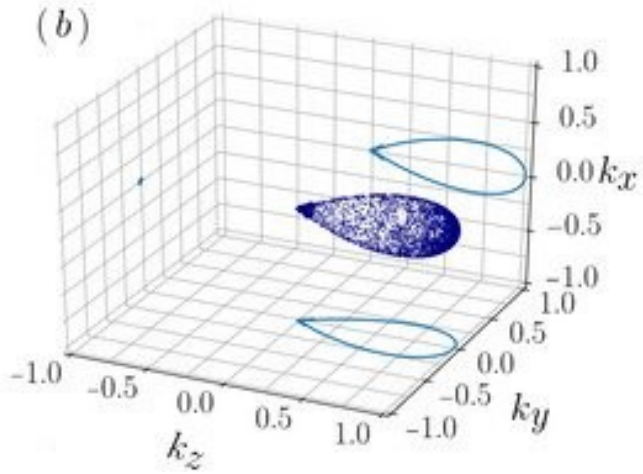

a
b
y
φ
z
x
c
(Q, C) = (+1, −1/2)
(−1, +1/2)
(+1, +1/2)
(−1, −1/2)
(a)
A_k
B_k
[Left circular]
[Right circular]
(b)
y
z
DW
B_{AC}
SW
x
SW source
DW
y
z
x
J_s^z
0
Torque on DW
Left circular SW
Right circular SW
x

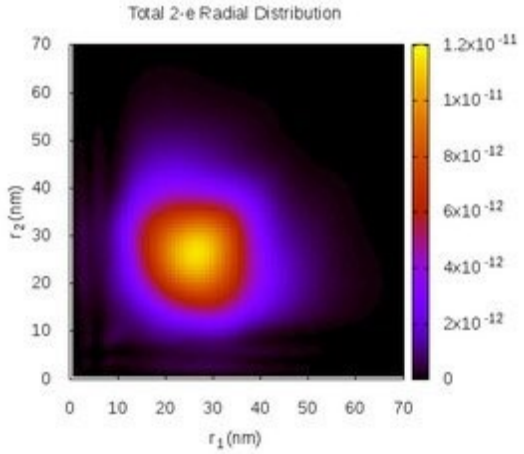

t = 0.0ms
11.36ms
12.6ms
13.94ms
29.94ms
35.1ms
(a1) Ψ1
(a2)
(a3)
(a4)
(a5)
(a6)
1.0N
0.94N
0.81N
0.65N
0.55N
0.55N
(b1) Ψ2
(b2)
(b3)
(b4)
(b5)
(b6)
0.0N
0.06N
0.19N
0.35N
0.45N
0.45N
y(units of a_osc)
x(units of a_osc)
220
165
110
55
0

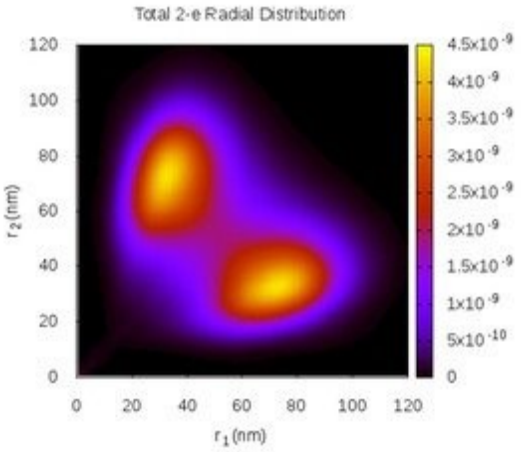

t = 0.0ms
12.6ms
13.42ms
13.94ms
14.56ms
26.22ms
(a1) Ψ1
(a2)
(a3)
(a4)
(a5)
(a6)
1.0N
0.9N
0.69N
0.48N
0.22N
0.0N
(b1) Ψ2
(b2)
(b3)
(b4)
(b5)
(b6)
0.0N
0.1N
0.31N
0.52N
0.78N
1.0N
y(units of a_osc)
x(units of a_osc)
220
165
110
55
0

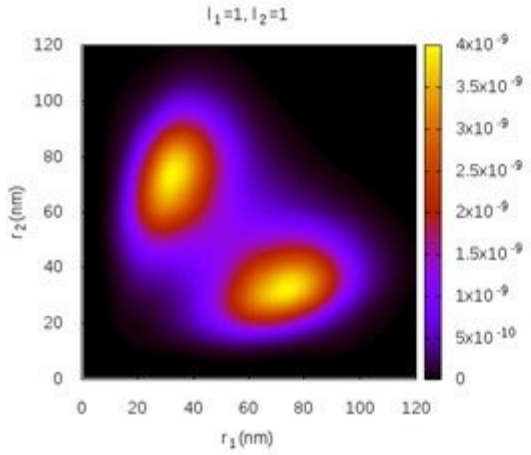

t = 0.0ms
10.84ms
11.46ms
11.98ms
12.7ms
26.22ms
(c1) Ψ1
(c2)
(c3)
(c4)
(c5)
(c6)
1.0N
0.89N
0.7N
0.48N
0.21N
0.0N
(d1) Ψ2
(d2)
(d3)
(d4)
(d5)
(d6)
0.0N
0.11N
0.3N
0.52N
0.79N
1.0N
y(units of a_osc)
x(units of a_osc)
220
165
110
55
0

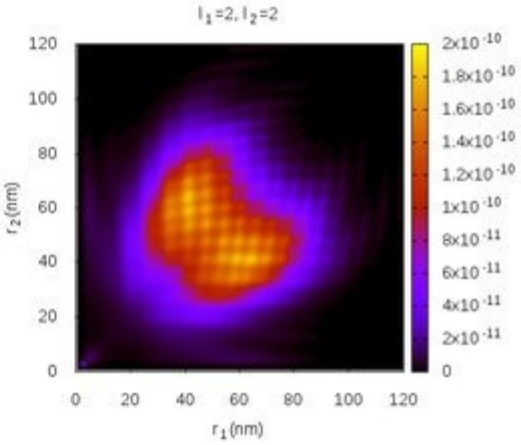

(a)
k0x
k0y
k0z

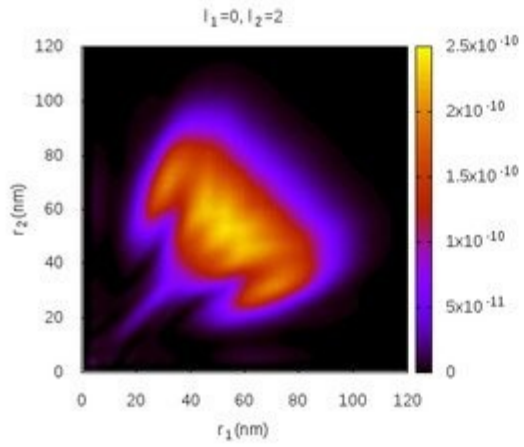

(b)
kx
ky
kz

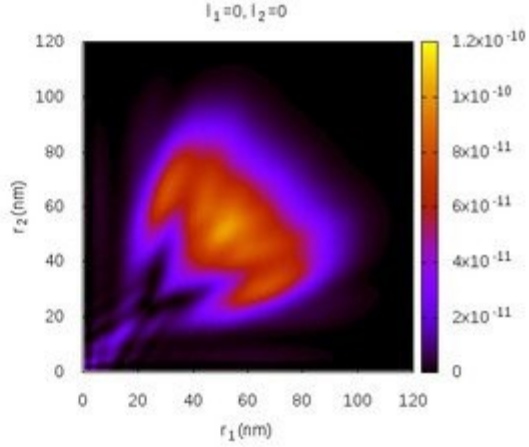

Total 2-e Radial Distribution
r2(nm)
r1(nm)

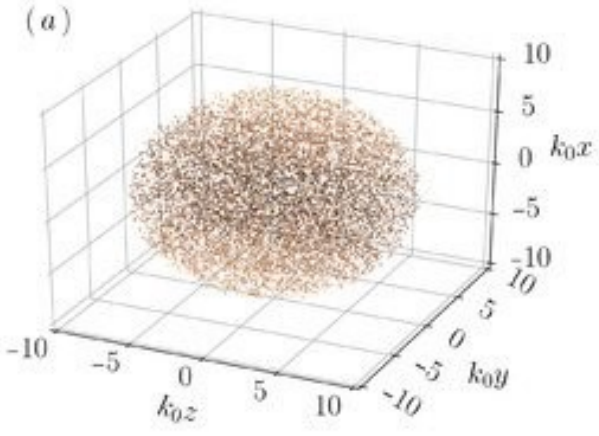

Total 2-e Radial Distribution
r2(nm)
r1(nm)

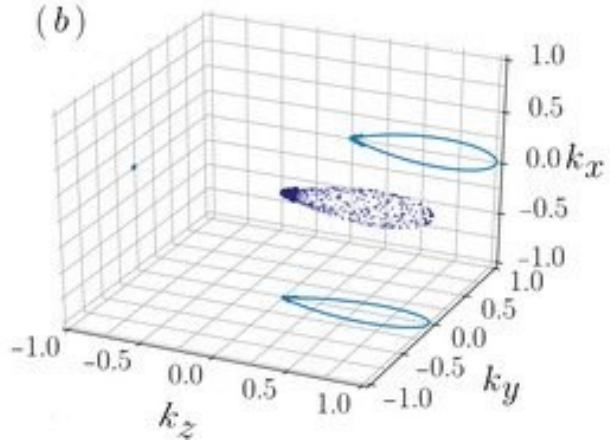

l1=1, l2=1
r2(nm)
r1(nm)

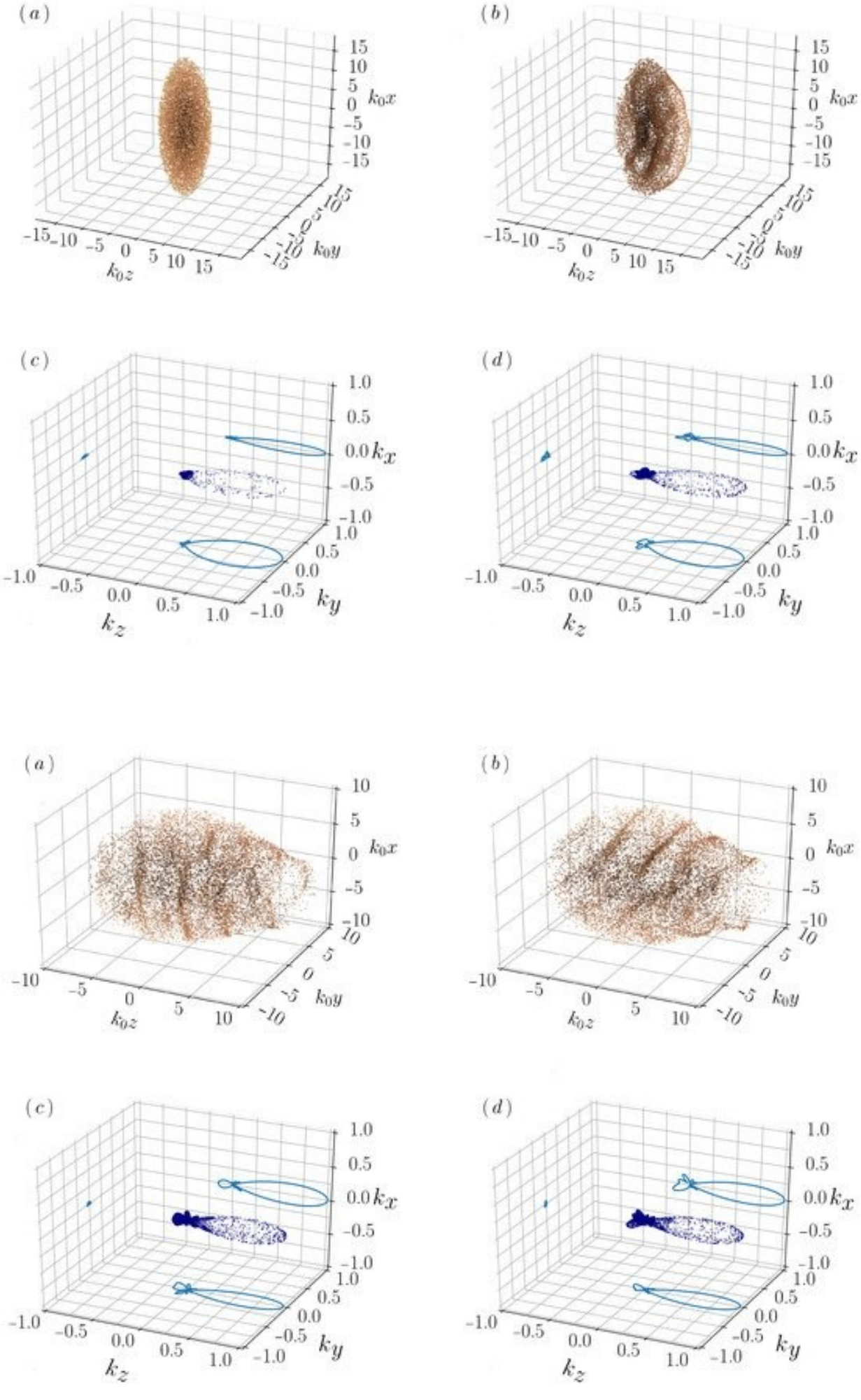

l1=2, l2=2
r2(nm)
r1(nm)

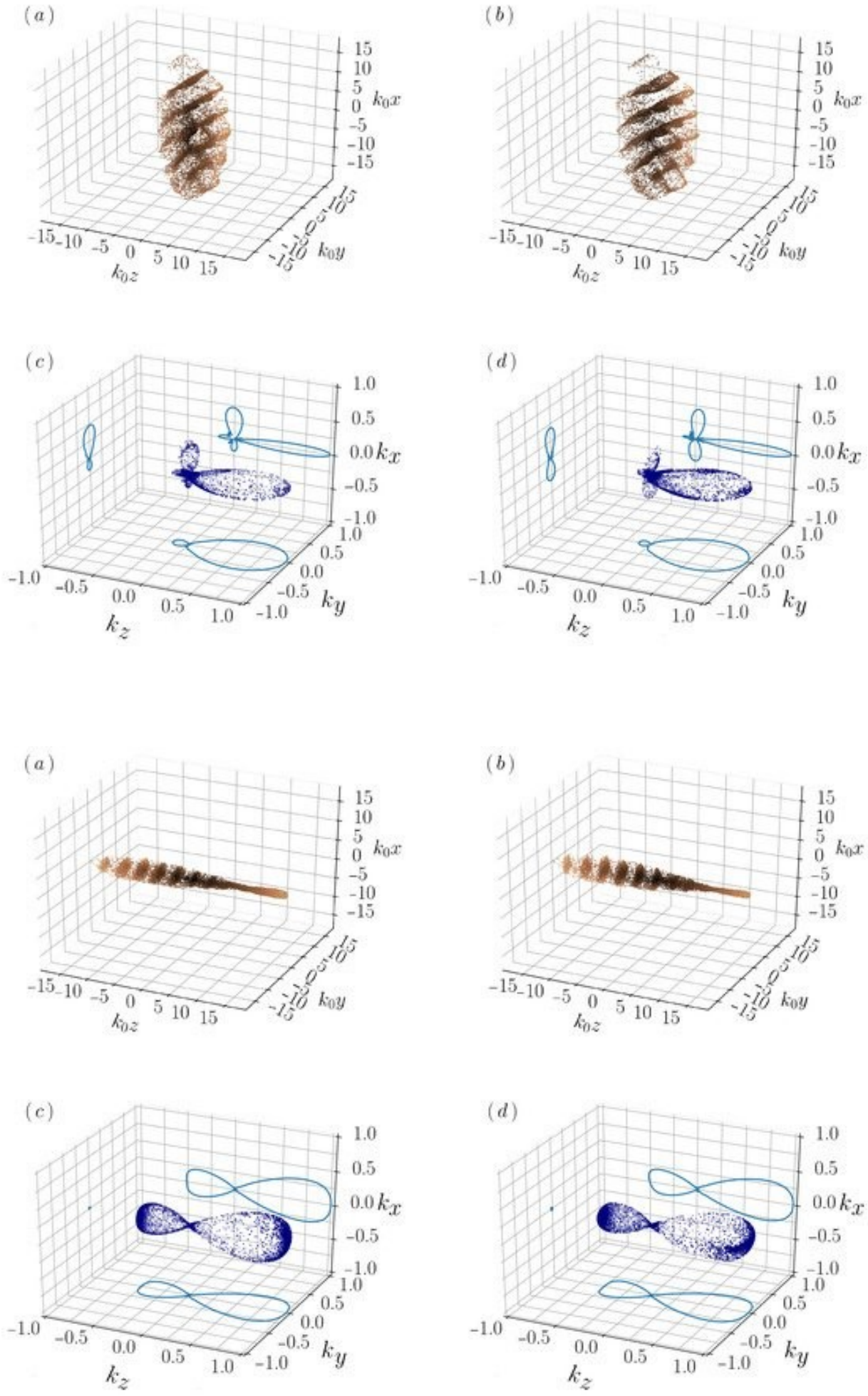

l1=0, l2=2
r2(nm)
r1(nm)

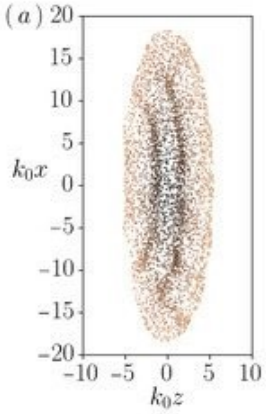

l1=0, l2=0
r2(nm)
r1(nm)

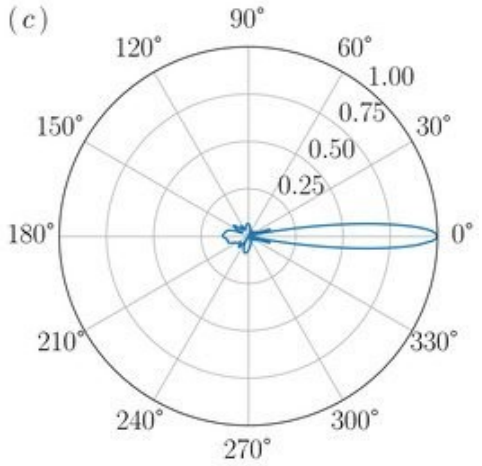

(a)
k0x
k0y
k0z

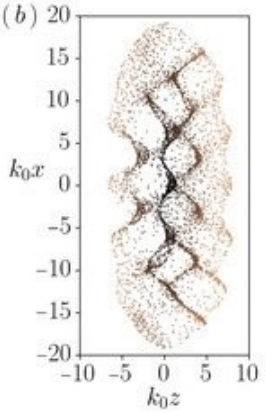

(b)
kx
ky
kz

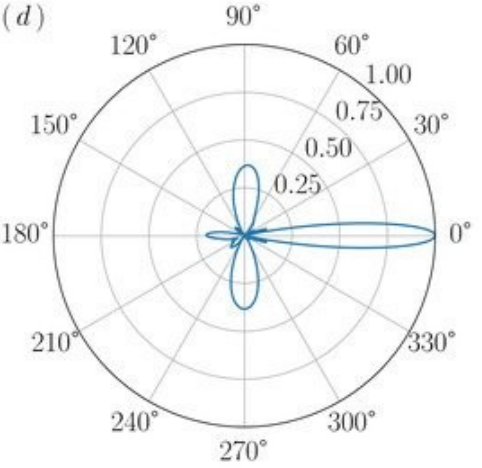

(a)
15
10
5
0
-5
-10
-15
k_0x
-15 -10 -5 0 5 10 15
k_0z
15 10 5 0 -5 -10 -15
k_0y
(b)
15
10
5
0
-5
-10
-15
k_0x
-15 -10 -5 0 5 10 15
k_0z
15 10 5 0 -5 -10 -15
k_0y
(c)
1.0
0.5
0.0
-0.5
-1.0
k_x
-1.0 -0.5 0.0 0.5 1.0
k_z
1.0 0.5 0.0 -0.5 -1.0
k_y
(d)
1.0
0.5
0.0
-0.5
-1.0
k_x
-1.0 -0.5 0.0 0.5 1.0
k_z
1.0 0.5 0.0 -0.5 -1.0
k_y
(a)
10
5
0
-5
-10
k_0x
-10 -5 0 5 10
k_0z
10 5 0 -5 -10
k_0y
(b)
10
5
0
-5
-10
k_0x
-10 -5 0 5 10
k_0z
10 5 0 -5 -10
k_0y
(c)
1.0
0.5
0.0
-0.5
-1.0
k_x
-1.0 -0.5 0.0 0.5 1.0
k_z
1.0 0.5 0.0 -0.5 -1.0
k_y
(d)
1.0
0.5
0.0
-0.5
-1.0
k_x
-1.0 -0.5 0.0 0.5 1.0
k_z
1.0 0.5 0.0 -0.5 -1.0
k_y

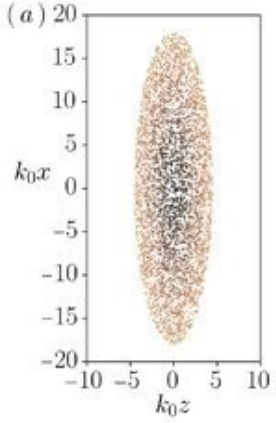

(a)
(b)
(c)
(d)
(a)
(b)
(c)
(d)
k_0x
k_0y
k_0z
k_x
k_y
k_z

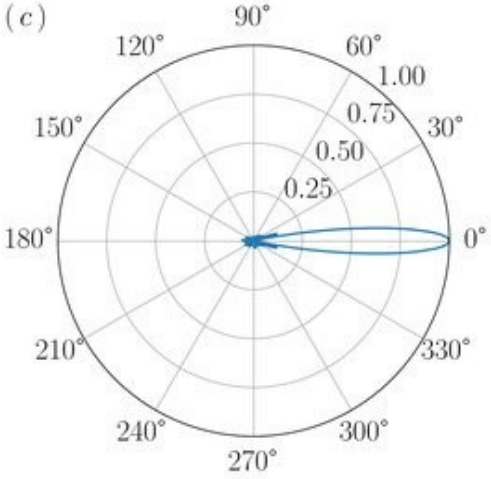

(a)
20
15
10
5
0
-5
-10
-15
-20
k_0x
-10 -5 0 5 10
k_0z

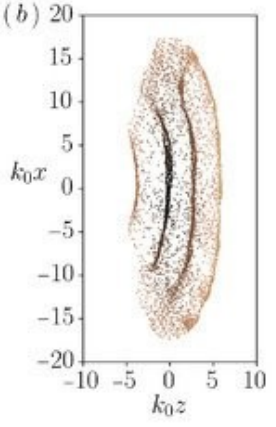

(c)
90°
120°
60°
1.00
0.75
0.50
0.25
150°
30°
180°
0°
210°
330°
240°
300°
270°

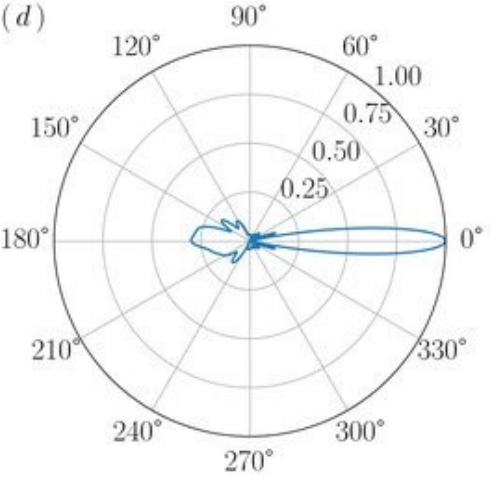

(b)
20
15
10
5
0
-5
-10
-15
-20
k_0x
-10 -5 0 5 10
k_0z

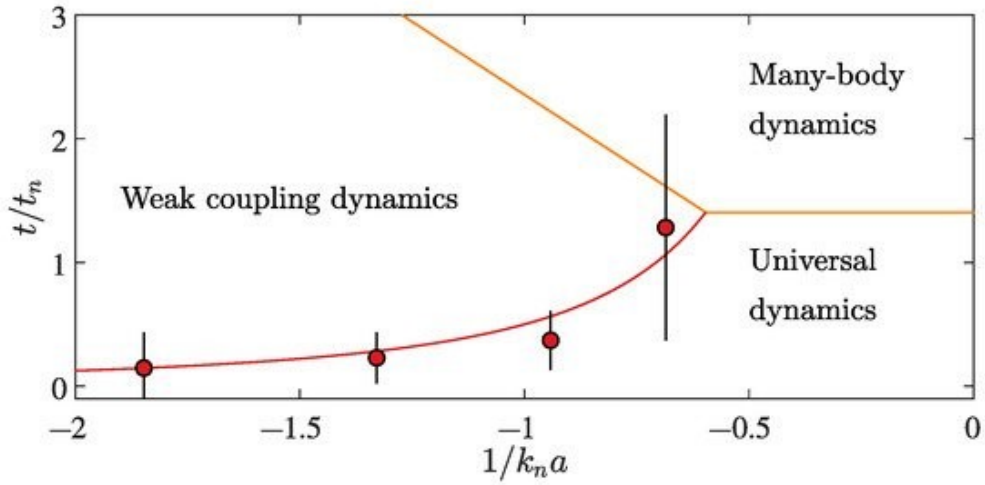

(d)
90°
120°
60°
1.00
0.75
0.50
0.25
150°
30°
180°
0°
210°
330°
240°
300°
270°

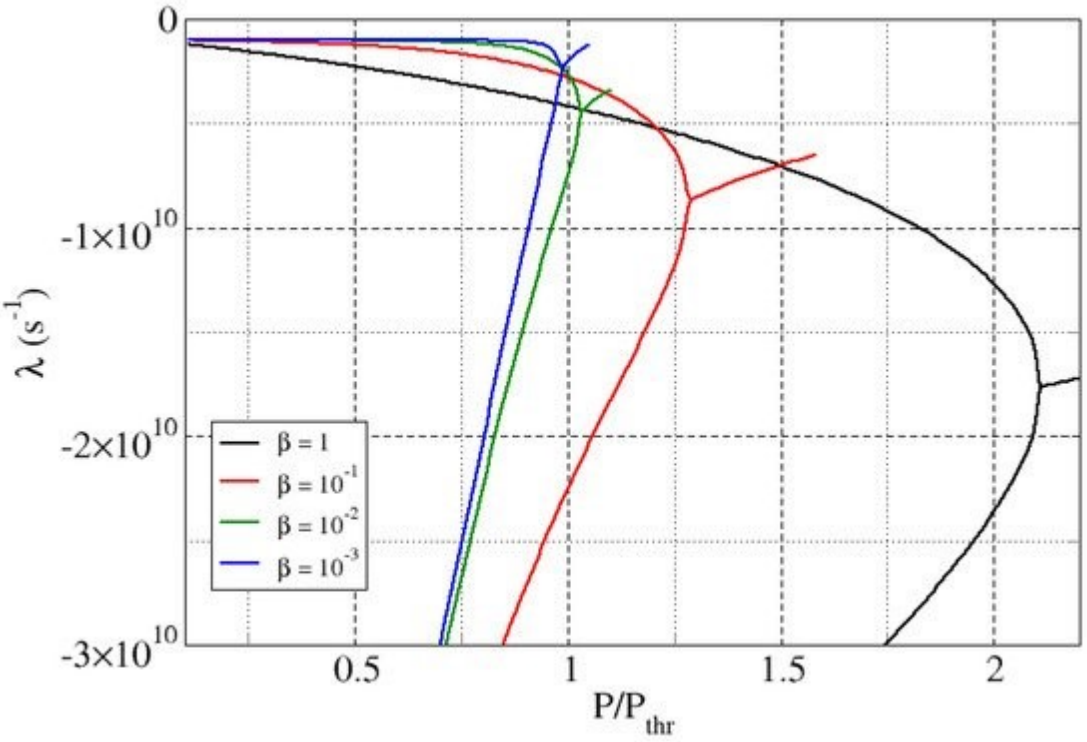

(a)
20
15
10
5
0
-5
-10
-15
-20
k_0x
-10 -5 0 5 10
k_0z

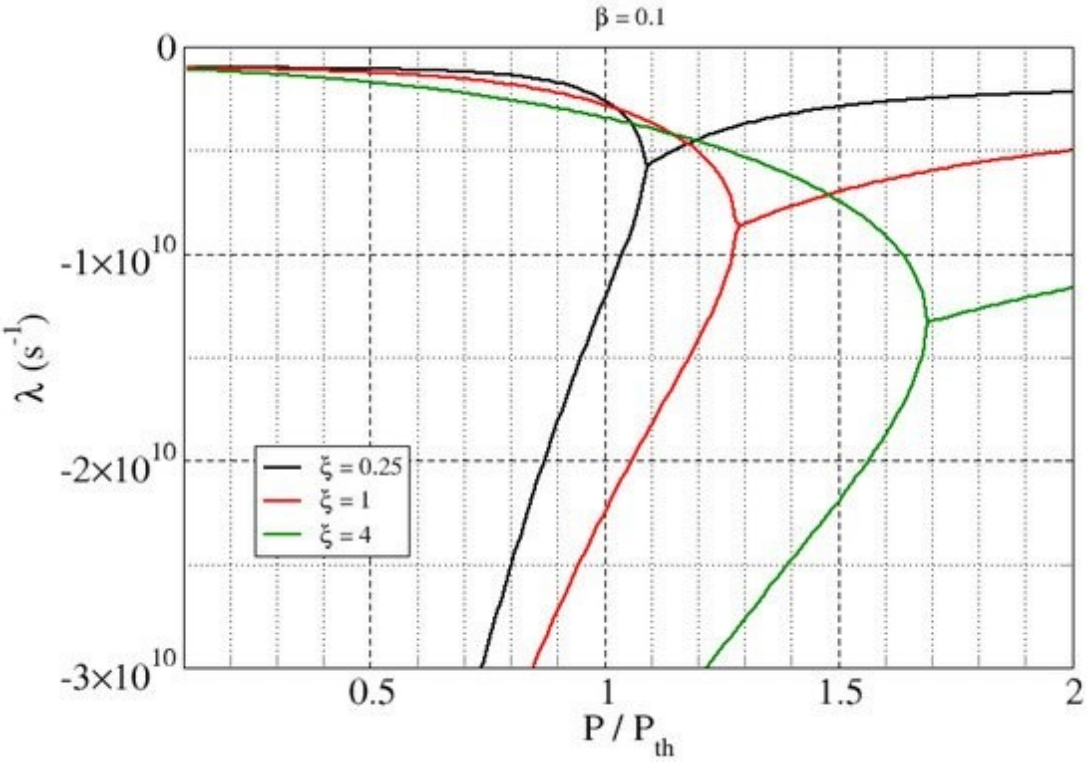

(c)
90°
120°
60°
1.00
0.75
0.50
0.25
150°
30°
180°
0°
210°
330°
240°
300°
270°

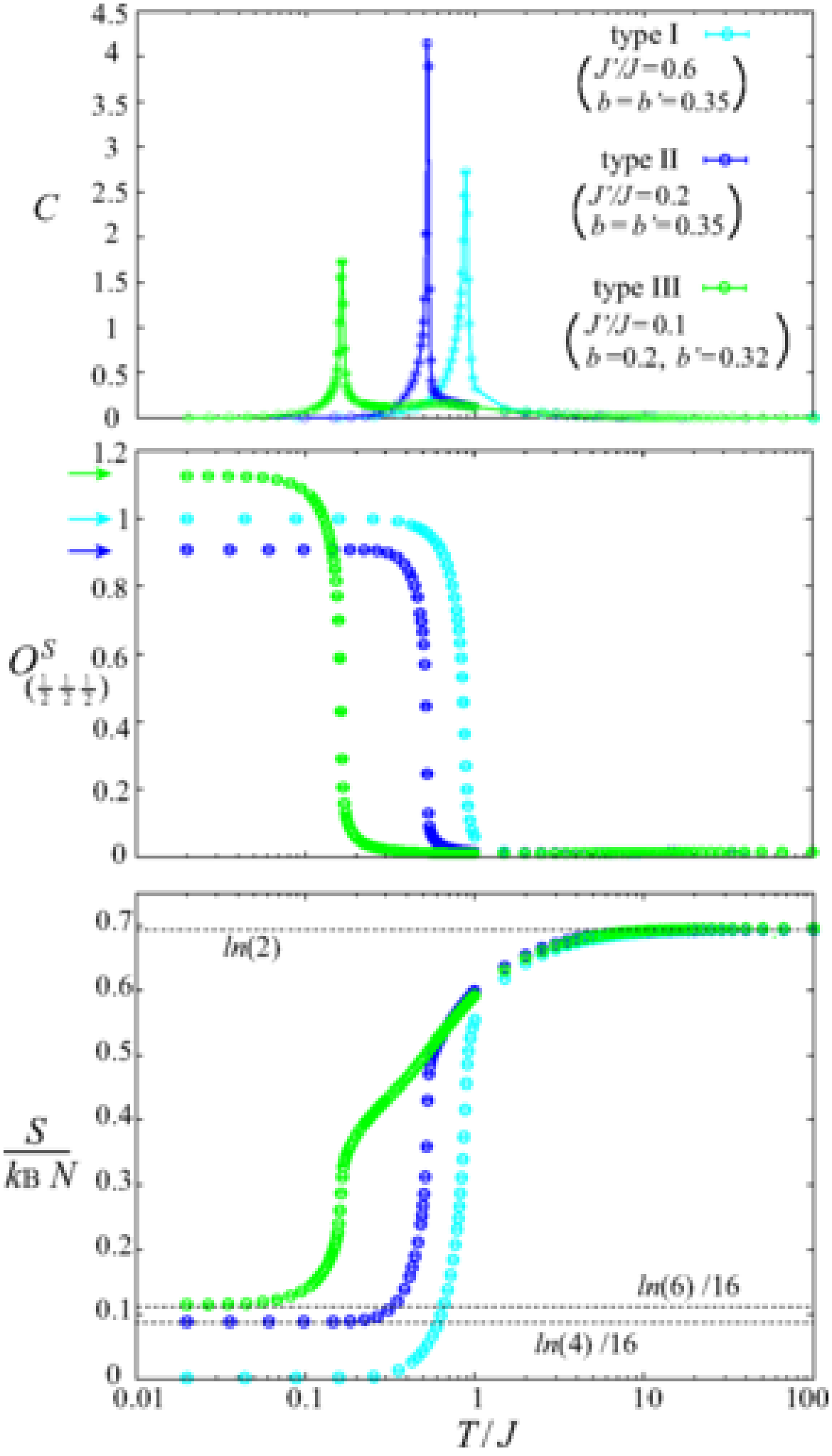

(b)
20
15
10
5
0
-5
-10
-15
-20
k_0x
-10 -5 0 5 10
k_0z

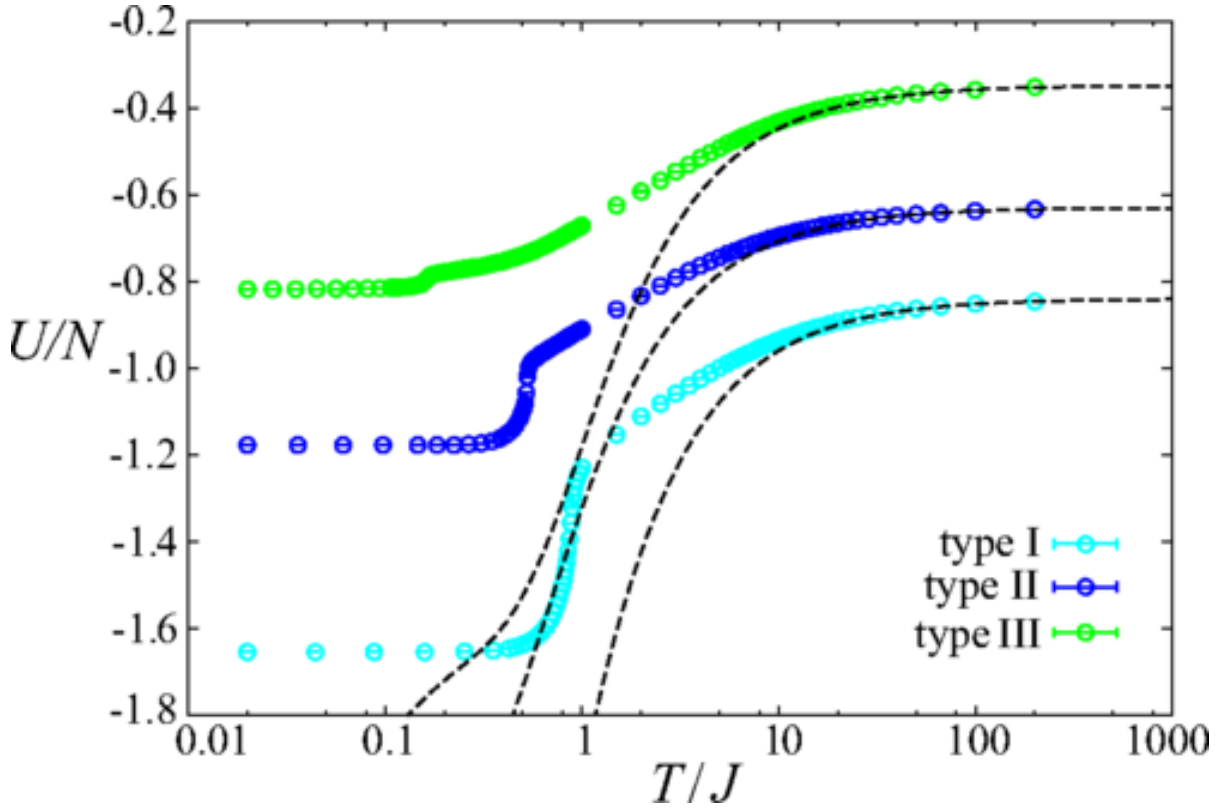

(d)
90°
120°
60°
1.00
0.75
0.50
0.25
150°
30°
180°
0°
210°
330°
240°
300°
270°

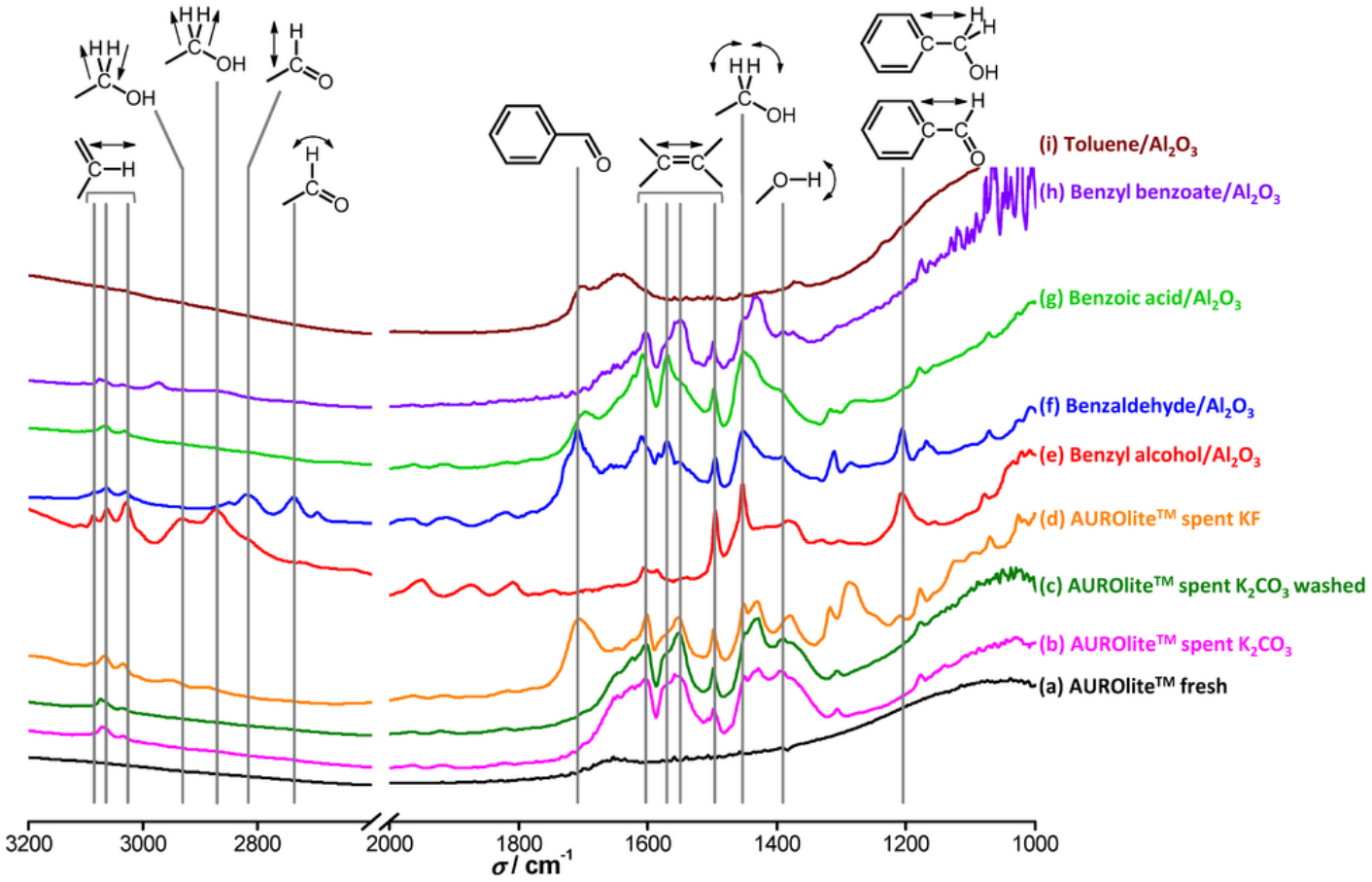

Many-body
dynamics
Weak coupling dynamics
Universal
dynamics
t/t_n
$1/k_n a$

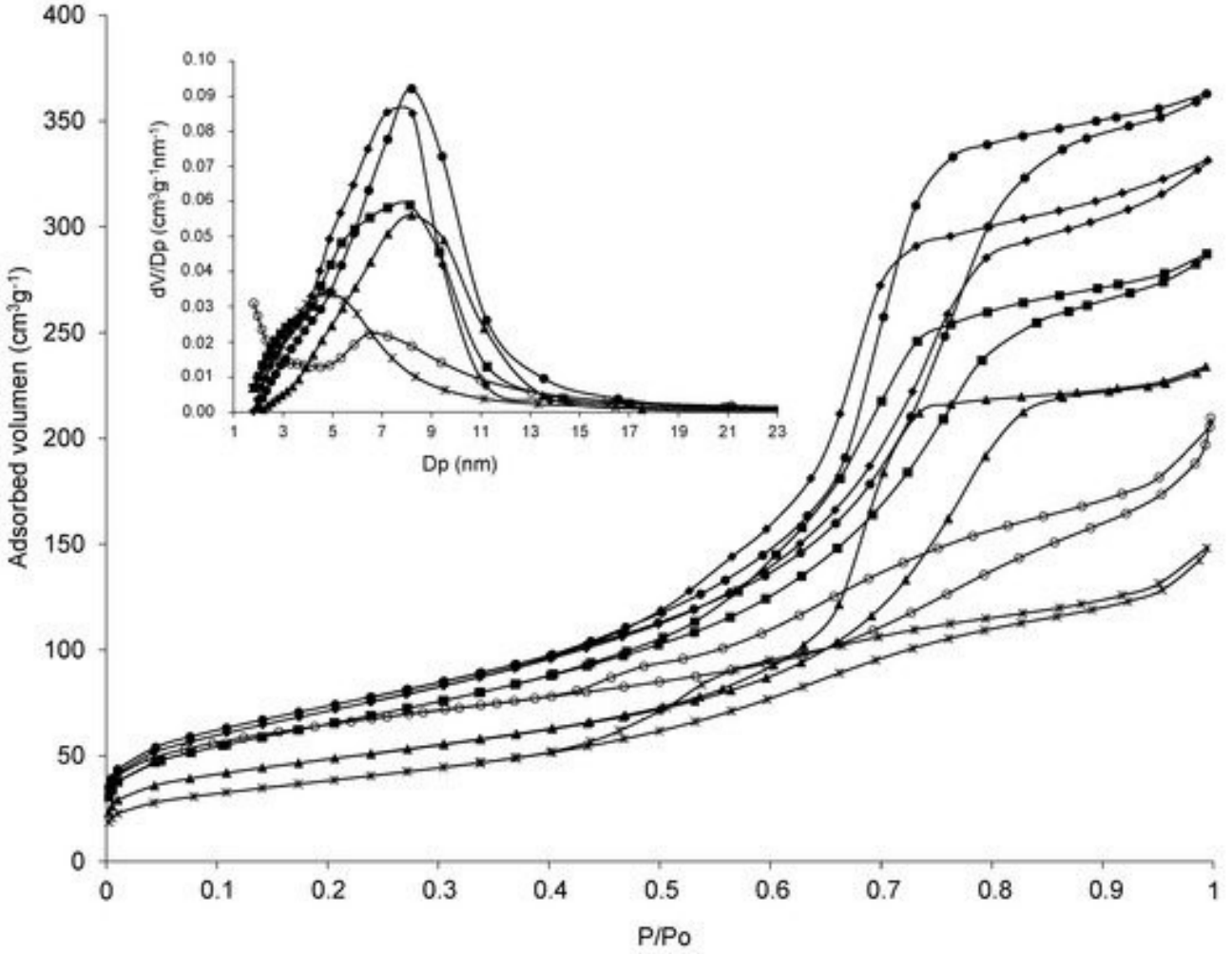

β = 1
β = 10^-1
β = 10^-2
β = 10^-3
λ (s^-1)
P/P_thr

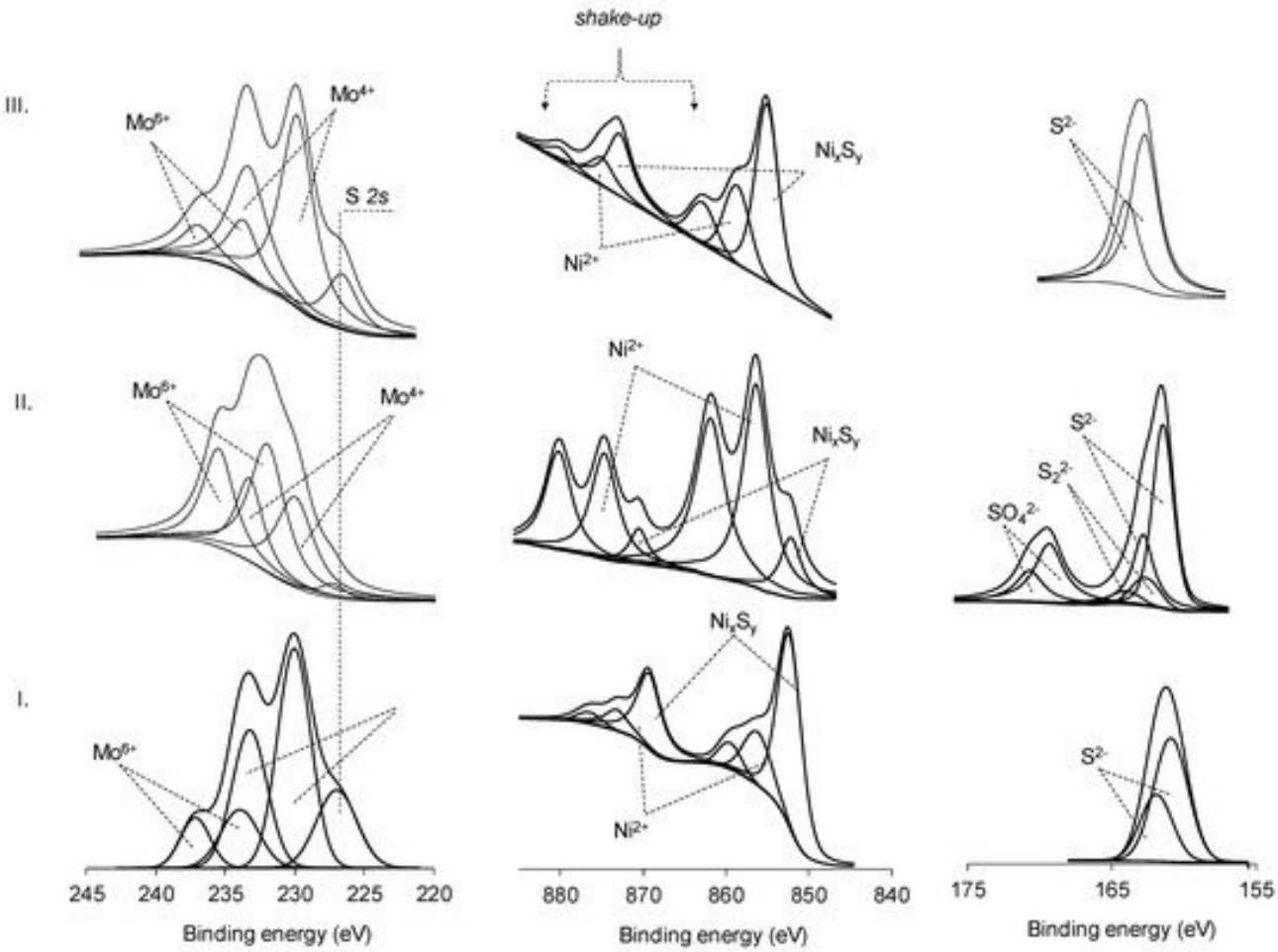

β = 0.1
ξ = 0.25
ξ = 1
ξ = 4
λ (s^-1)
P / P_th

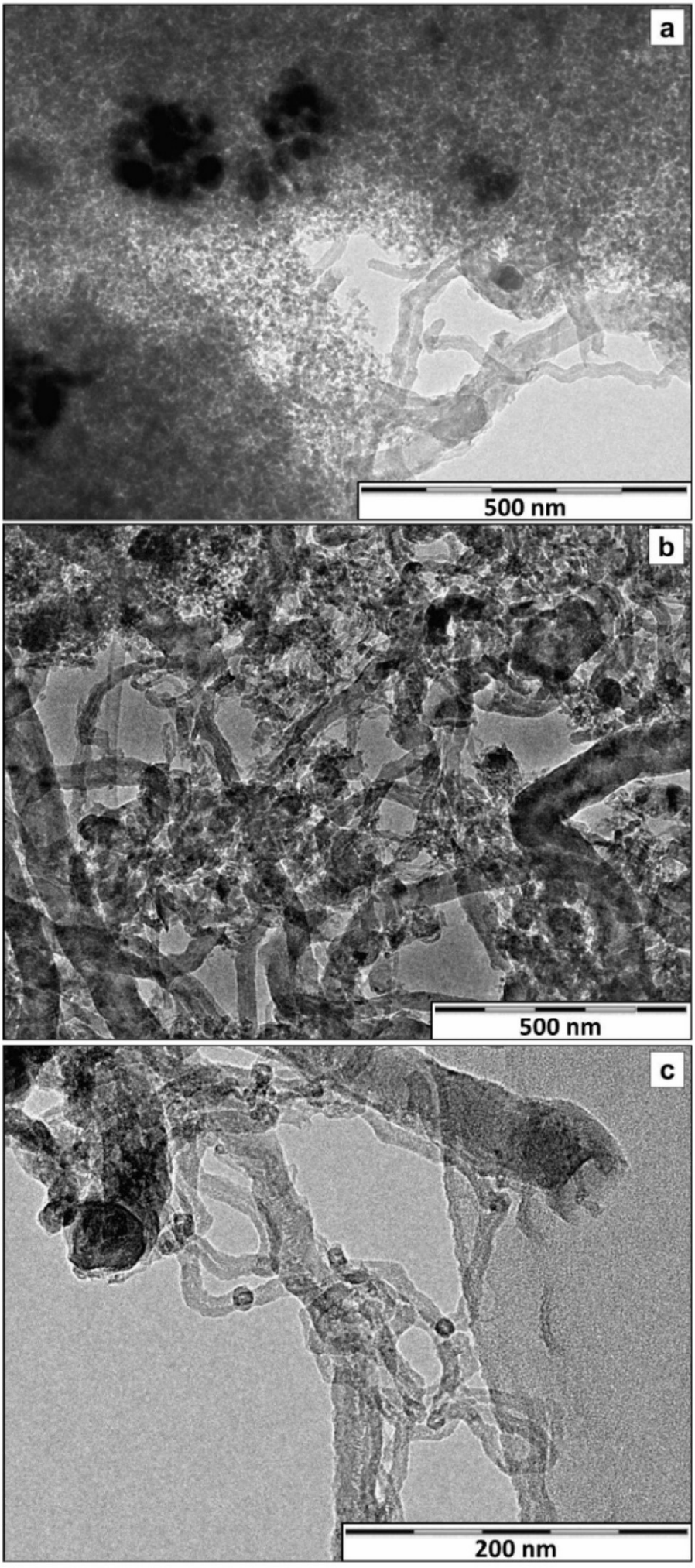

C
type I
(J'/J=0.6
b=b'=0.35)
type II
(J'/J=0.2
b=b'=0.35)
type III
(J'/J=0.1
b=0.2, b'=0.32)
$O^S_{(\frac{1}{2}\frac{1}{2}\frac{1}{2})}$
S / kB N
ln(2)
ln(6) /16
ln(4) /16
T / J

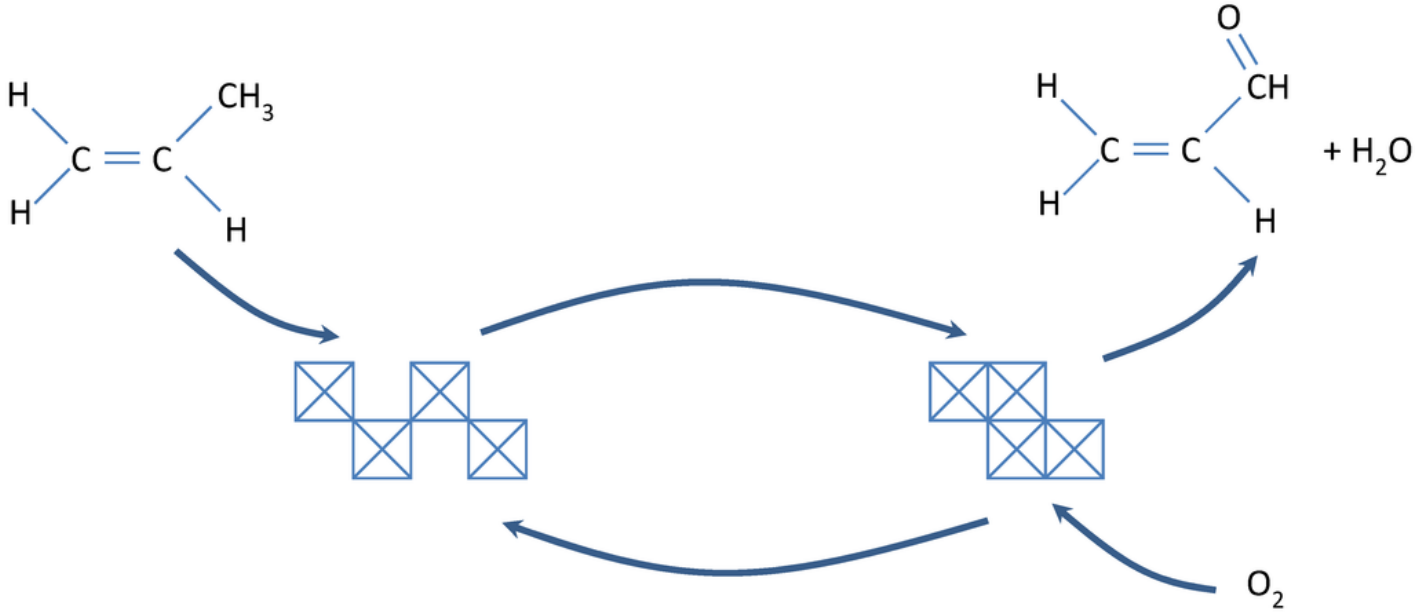

-0.2
-0.4
-0.6
-0.8
-1.0
-1.2
-1.4
-1.6
-1.8
U/N
0.01
0.1
1
10
100
1000
T / J
type I
type II
type III

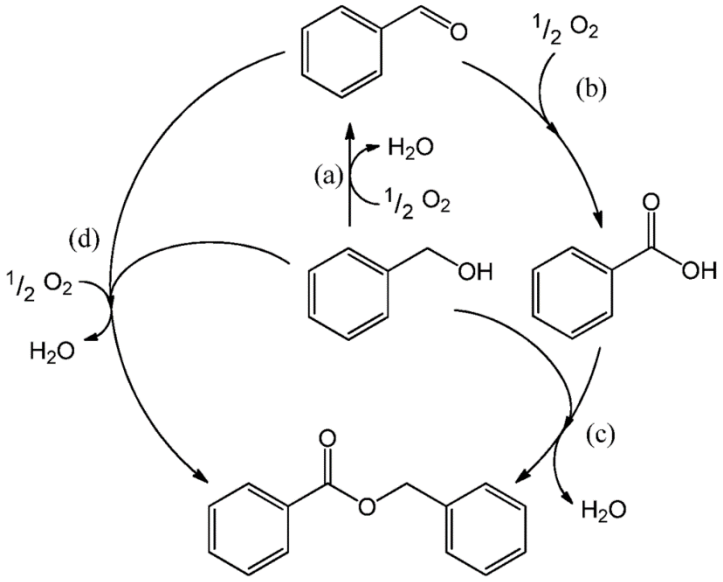

(i) Toluene/Al2O3
(h) Benzyl benzoate/Al2O3
(g) Benzoic acid/Al2O3
(f) Benzaldehyde/Al2O3
(e) Benzyl alcohol/Al2O3
(d) AUROlite™ spent KF
(c) AUROlite™ spent K2CO3 washed
(b) AUROlite™ spent K2CO3
(a) AUROlite™ fresh
3200
3000
2800
2000
1800
1600
1400
1200
1000
σ / cm-1

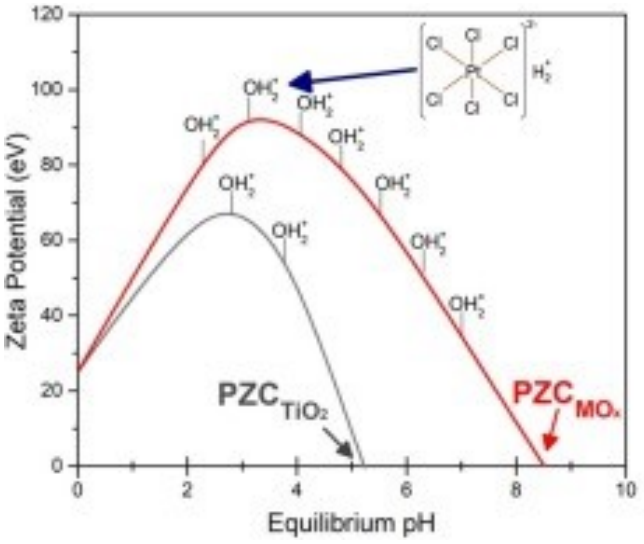

Adsorbed volumen (cm3g-1)
P/Po
dV/Dp (cm3g-1nm-1)
Dp (nm)

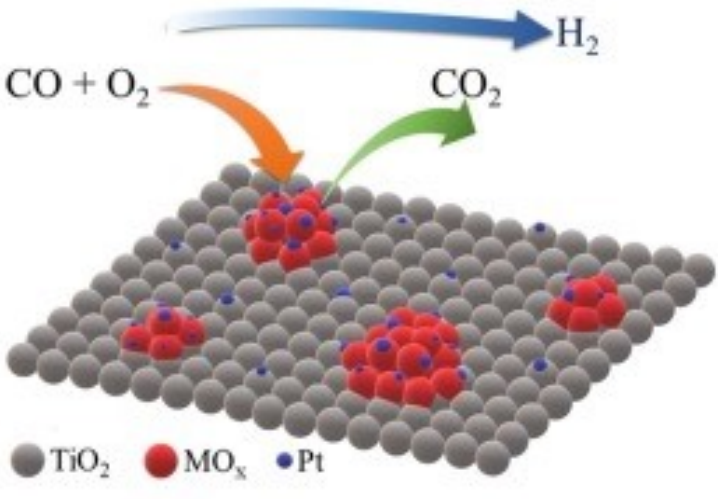

shake-up
III.
II.
I.
Mo6+
Mo4+
S 2s
NixSy
Ni2+
S2-
S22-
SO42-
Binding energy (eV)

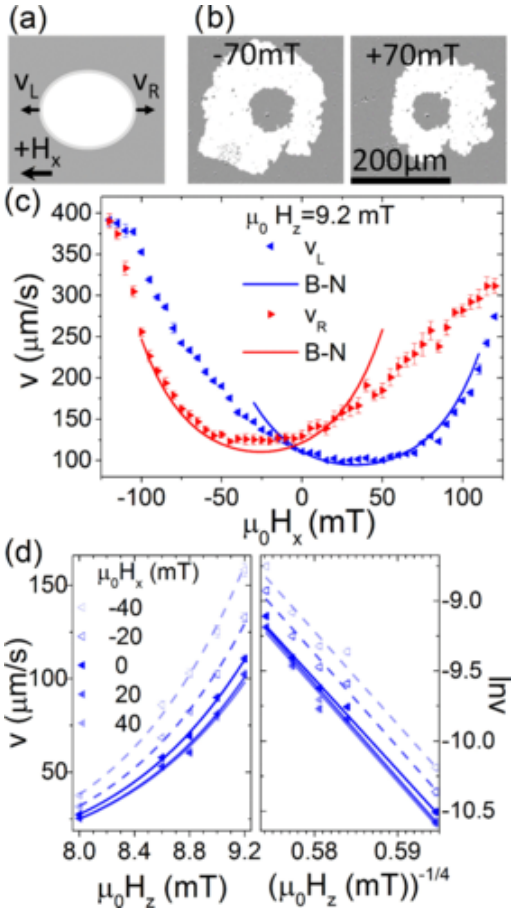

a
500 nm
b
500 nm
c
200 nm

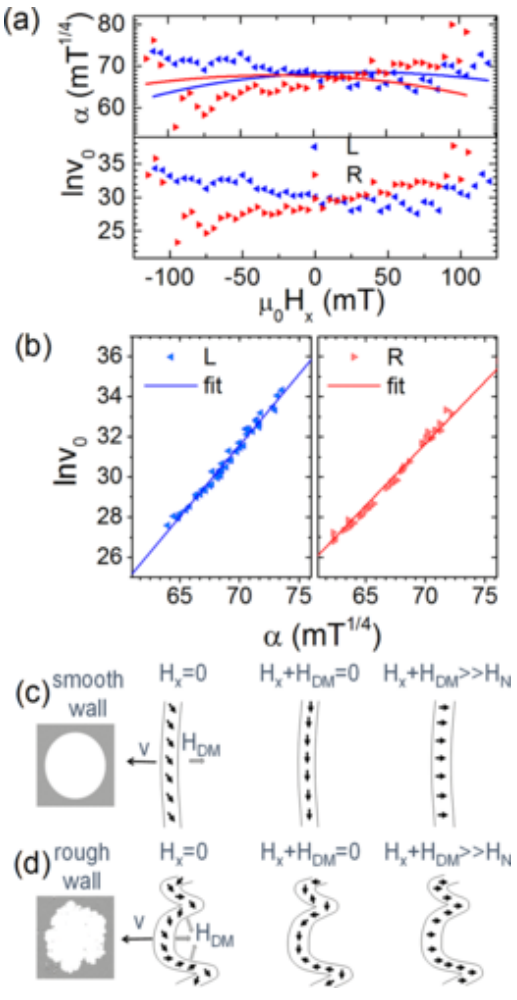

H
CH3
C
C
H
H
O
CH
H
C
C
H
H
+ H2O
O2


O
1/2 O2
(b)
(a)
H2O
1/2 O2
(d)
1/2 O2
H2O
OH
O
OH
(c)
O
O
H2O

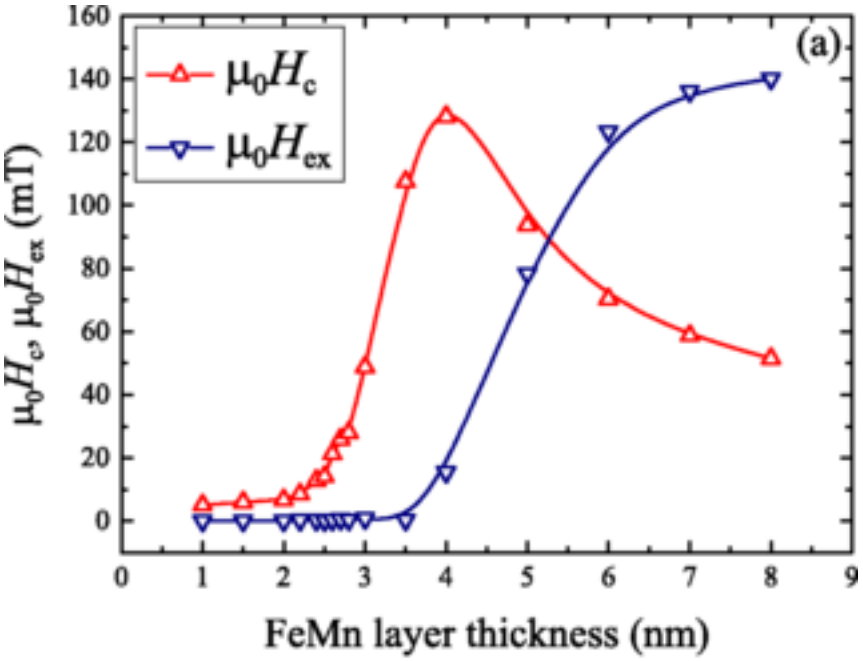

Zeta Potential (eV)
Equilibrium pH
PZC TiO2
PZC MO.
0
20
40
60
80
100
120
0
2
4
6
8
10

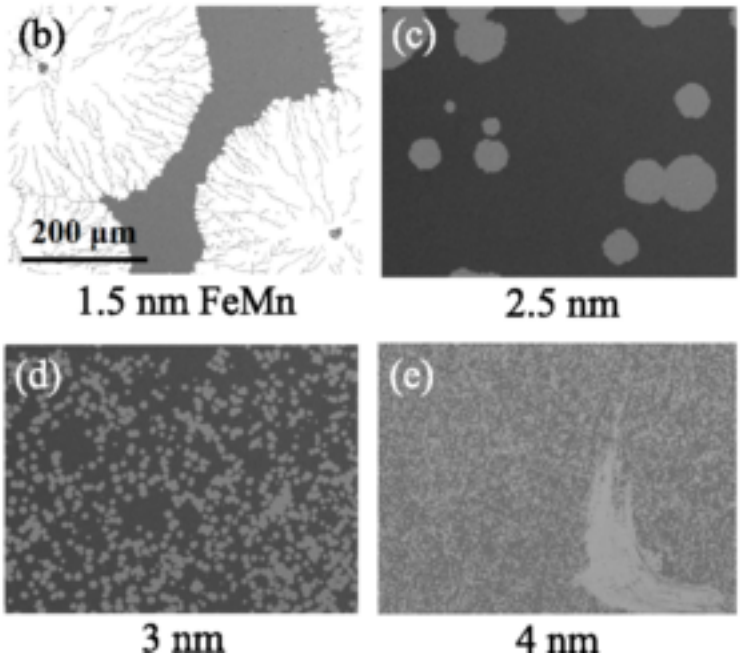

H2
CO + O2
CO2
TiO2
MOx
Pt

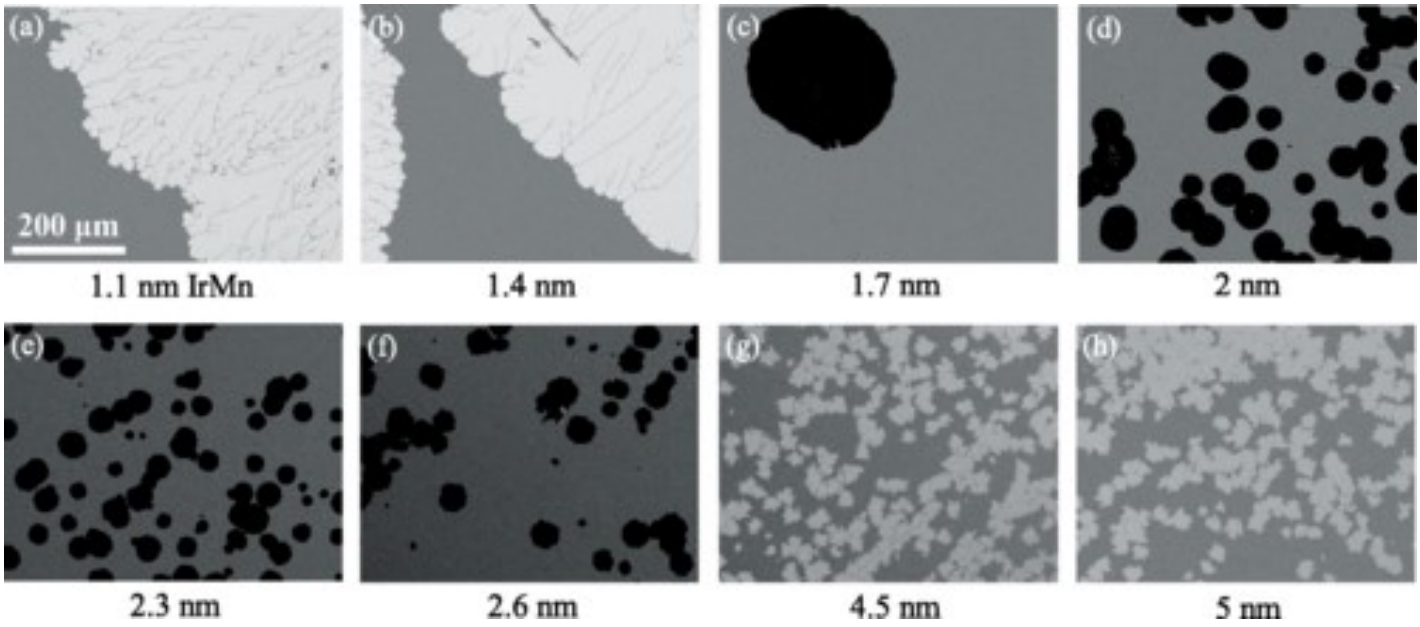

(a)
(b)
v_L
v_R
$+H_x$
-70mT
+70mT
200μm
(c)
$\mu_0 H_z$=9.2 mT
v_L
B-N
v_R
B-N
v (μm/s)
$\mu_0 H_x$ (mT)
(d)
$\mu_0 H_x$ (mT)
-40
-20
0
20
40
v (μm/s)
lnv
$\mu_0 H_z$ (mT)
$(\mu_0 H_z$ (mT))$^{-1/4}$

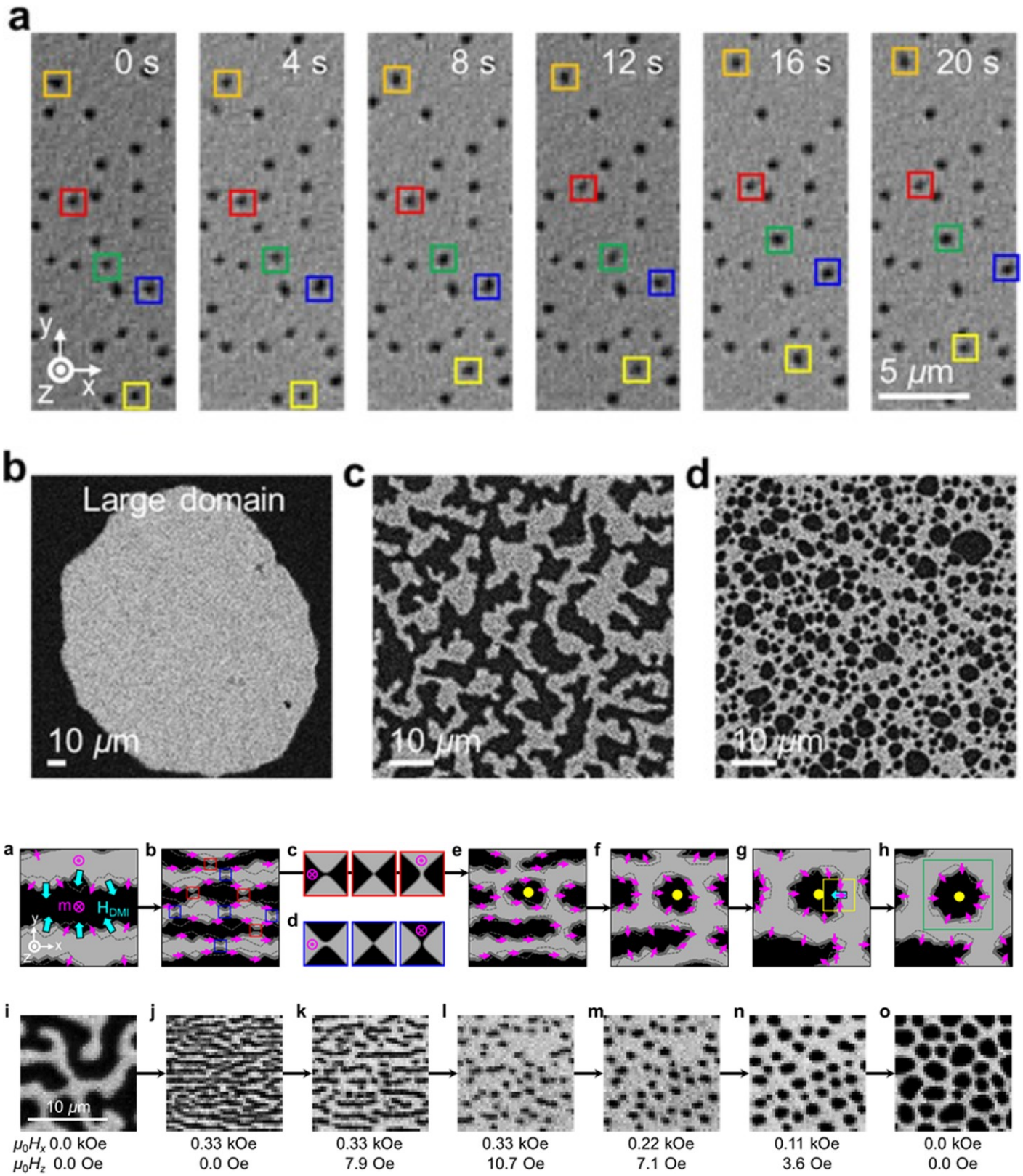

(a)
α ($mT^{1/4}$)
lnv_0
L
R
$\mu_0 H_x$ (mT)
(b)
L
fit
R
fit
lnv_0
α ($mT^{1/4}$)

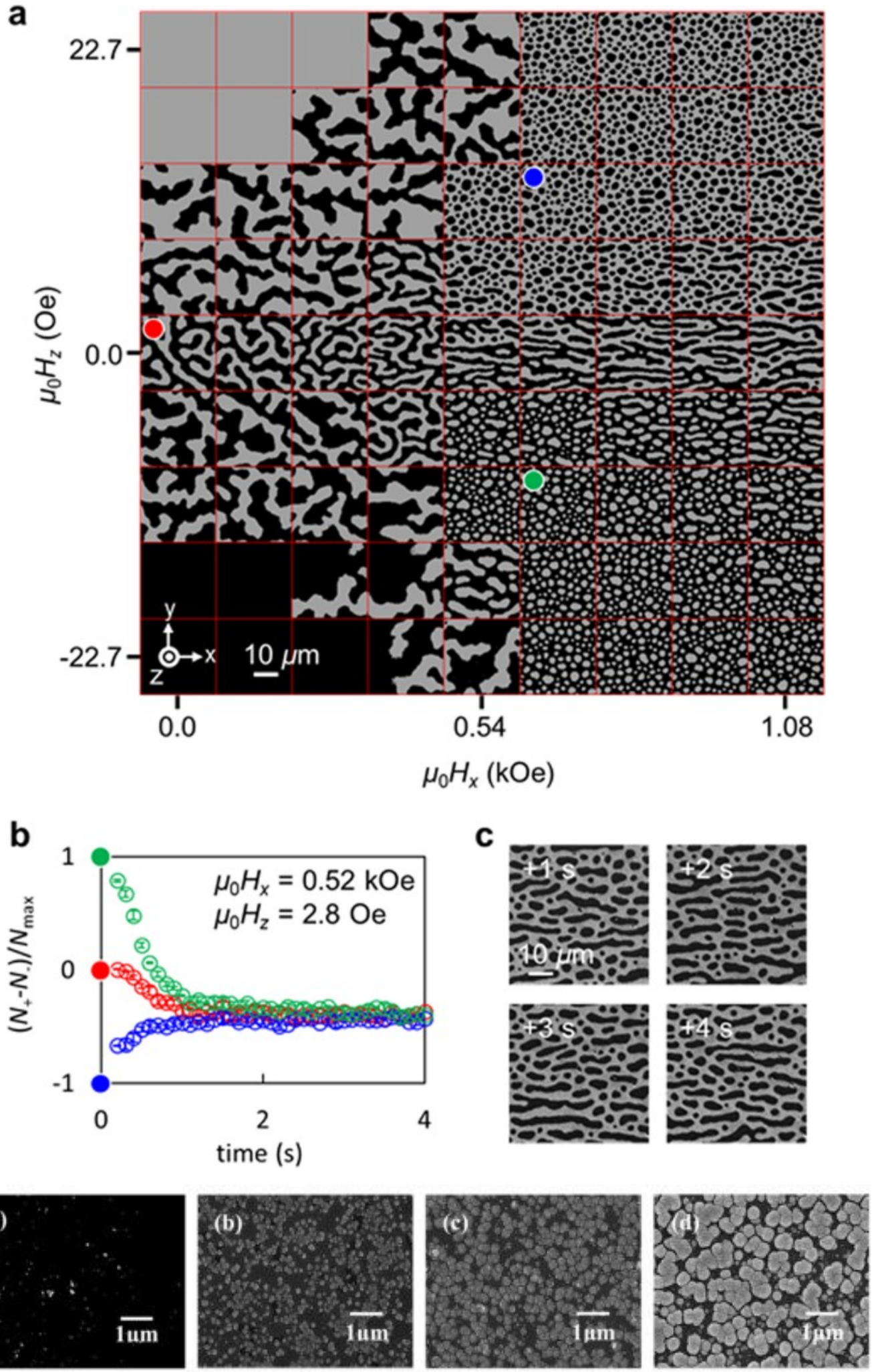
(c)
smooth wall
H_x=0
H_x+H_{DM}=0
$H_x+H_{DM}>>H_N$
v
H_{DM}
(d)
rough wall
H_x=0
H_x+H_{DM}=0
$H_x+H_{DM}>>H_N$
v
H_{DM}

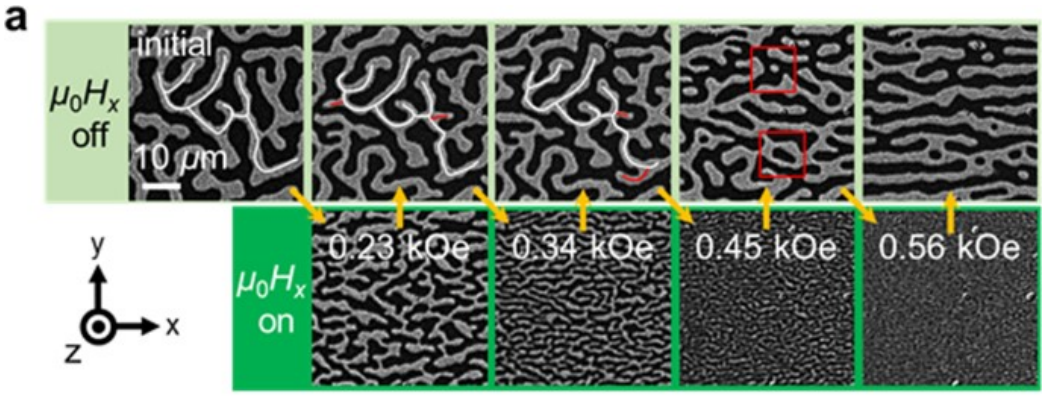

(a)
$\mu_0 H_c$
$\mu_0 H_{ex}$
$\mu_0 H_c$, $\mu_0 H_{ex}$ (mT)
FeMn layer thickness (nm)

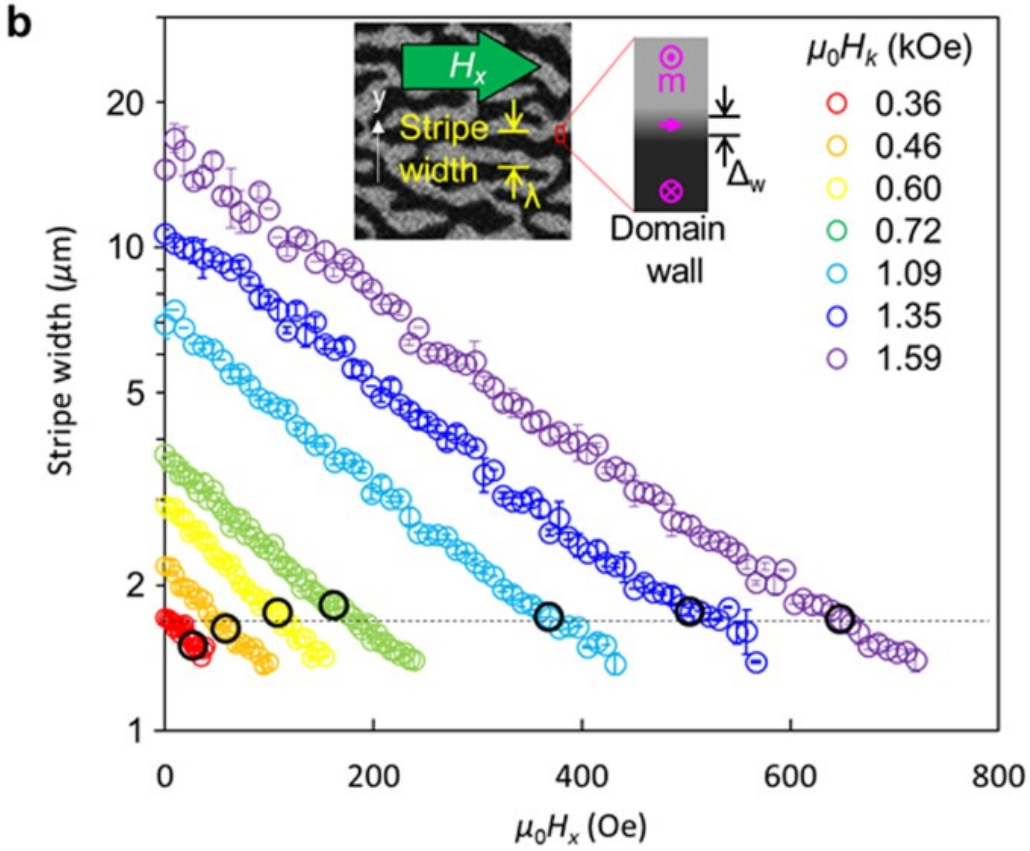

(b)
200 µm
1.5 nm FeMn
(c)
2.5 nm
(d)
3 nm
(e)
4 nm

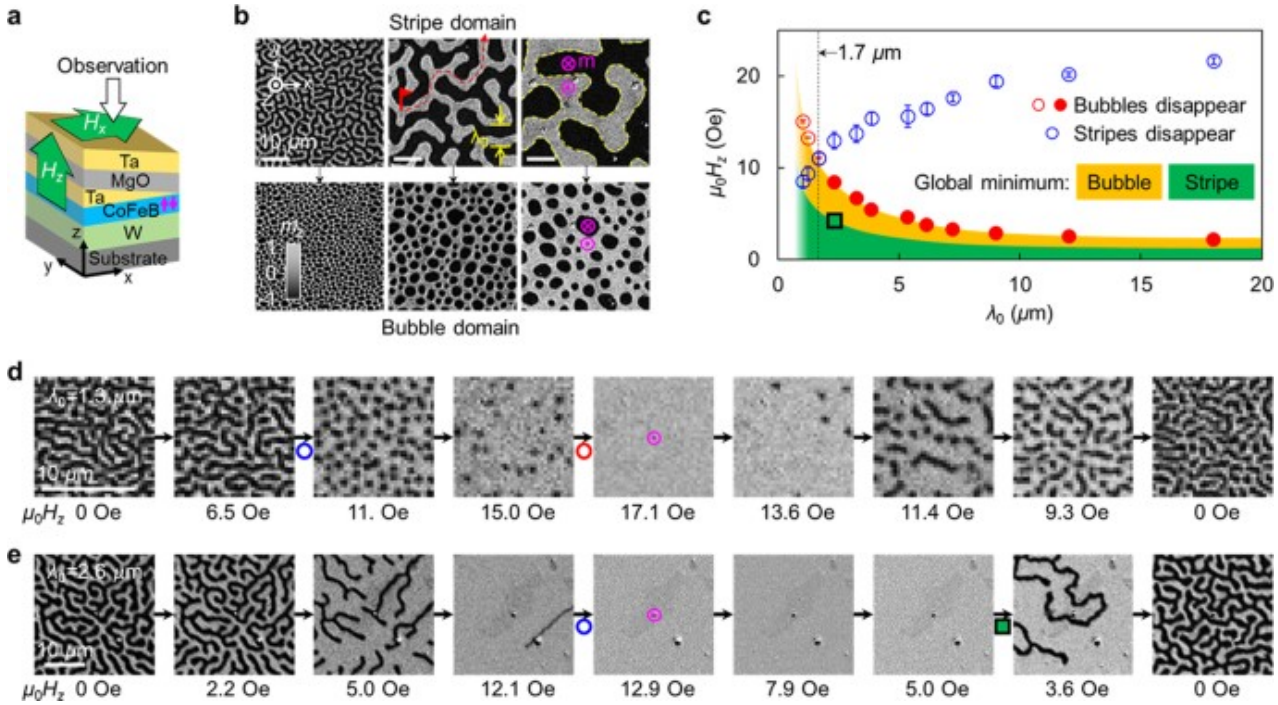

(a)
200 µm
1.1 nm IrMn
(b)
1.4 nm
(c)
1.7 nm
(d)
2 nm
(e)
2.3 nm
(f)
2.6 nm
(g)
4.5 nm
(h)
5 nm

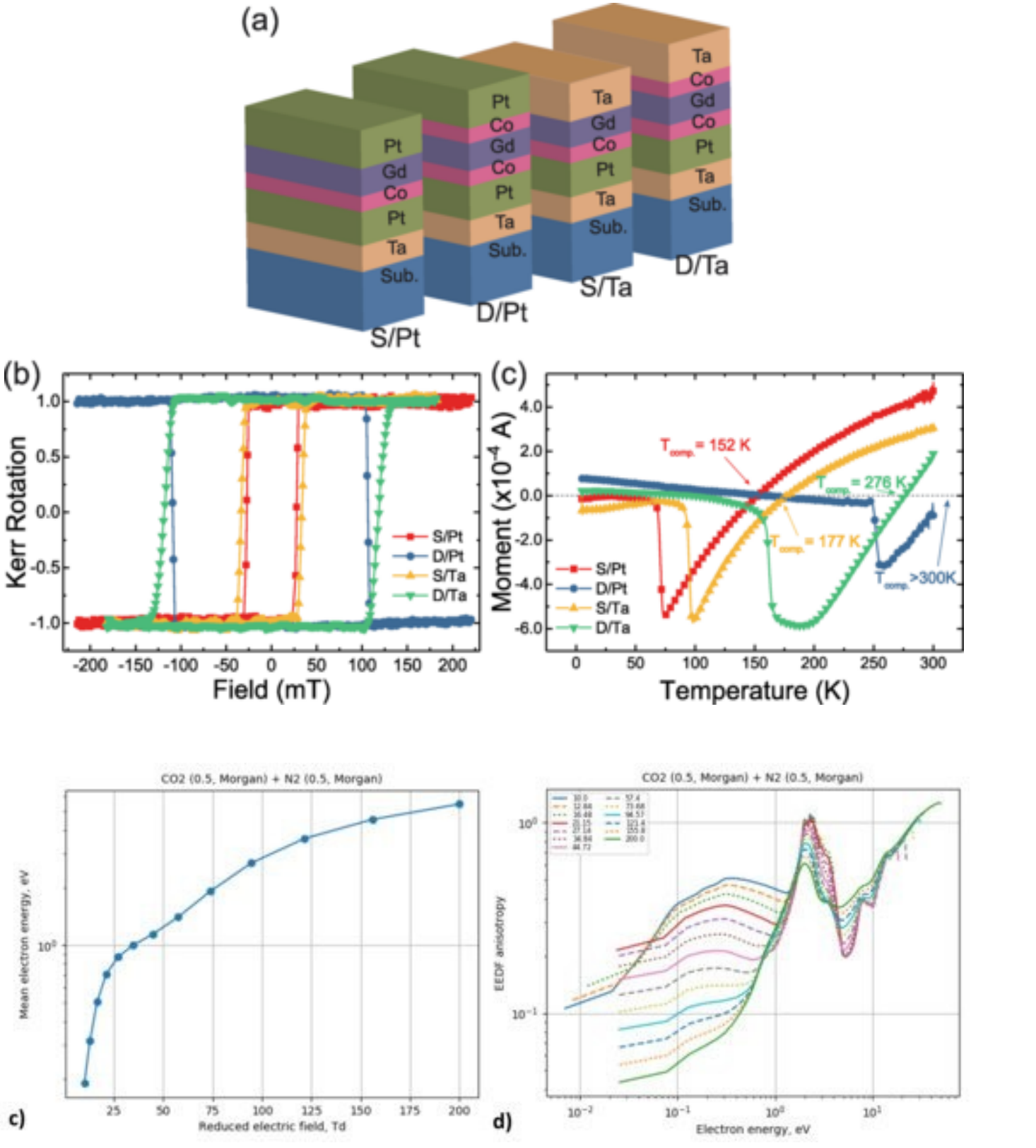

a
0 s
4 s
8 s
12 s
16 s
20 s
y
z
x
5 μm
b
Large domain
10 μm
c
10 μm
d
10 μm
a
b
c
d
e
f
g
h
m
H_DMI
i
j
k
l
m
n
o
10 μm
μ0Hx 0.0 kOe
μ0Hz 0.0 Oe
0.33 kOe
0.0 Oe
0.33 kOe
7.9 Oe
0.33 kOe
10.7 Oe
0.22 kOe
7.1 Oe
0.11 kOe
3.6 Oe
0.0 kOe
0.0 Oe

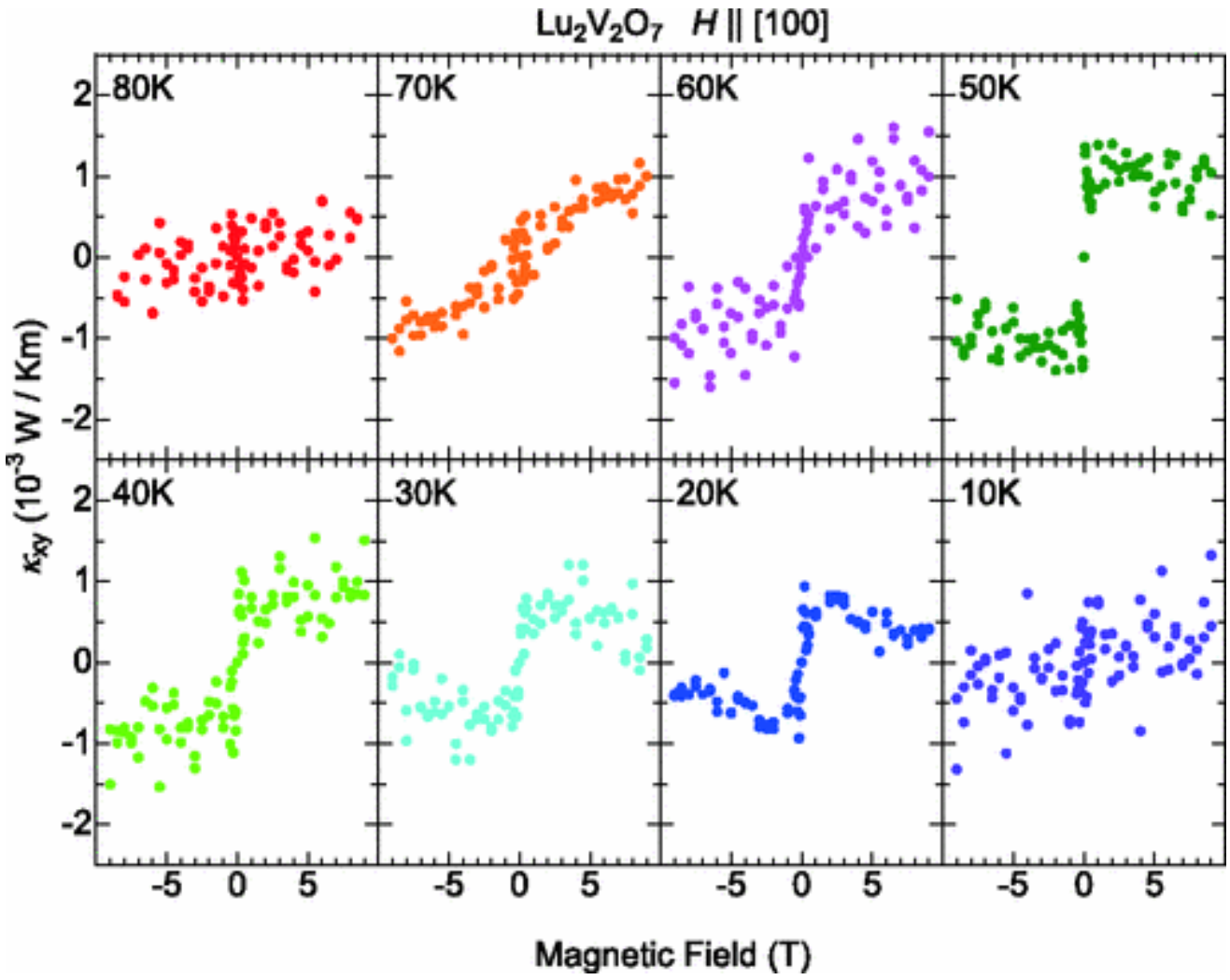

a
22.7
0.0
-22.7
$\mu_0 H_z$ (Oe)
y
x
z
10 μm
0.0
0.54
1.08
$\mu_0 H_x$ (kOe)
b
1
0
-1
$(N_+ - N_-)/(N_+ + N_-)$
$\mu_0 H_x$ = 0.52 kOe
$\mu_0 H_z$ = 2.8 Oe
0
2
4
time (s)
c
+1 s
+2 s
10 μm
+3 s
+4 s
(a)
1μm
(b)
1μm
(c)
1μm
(d)
1μm

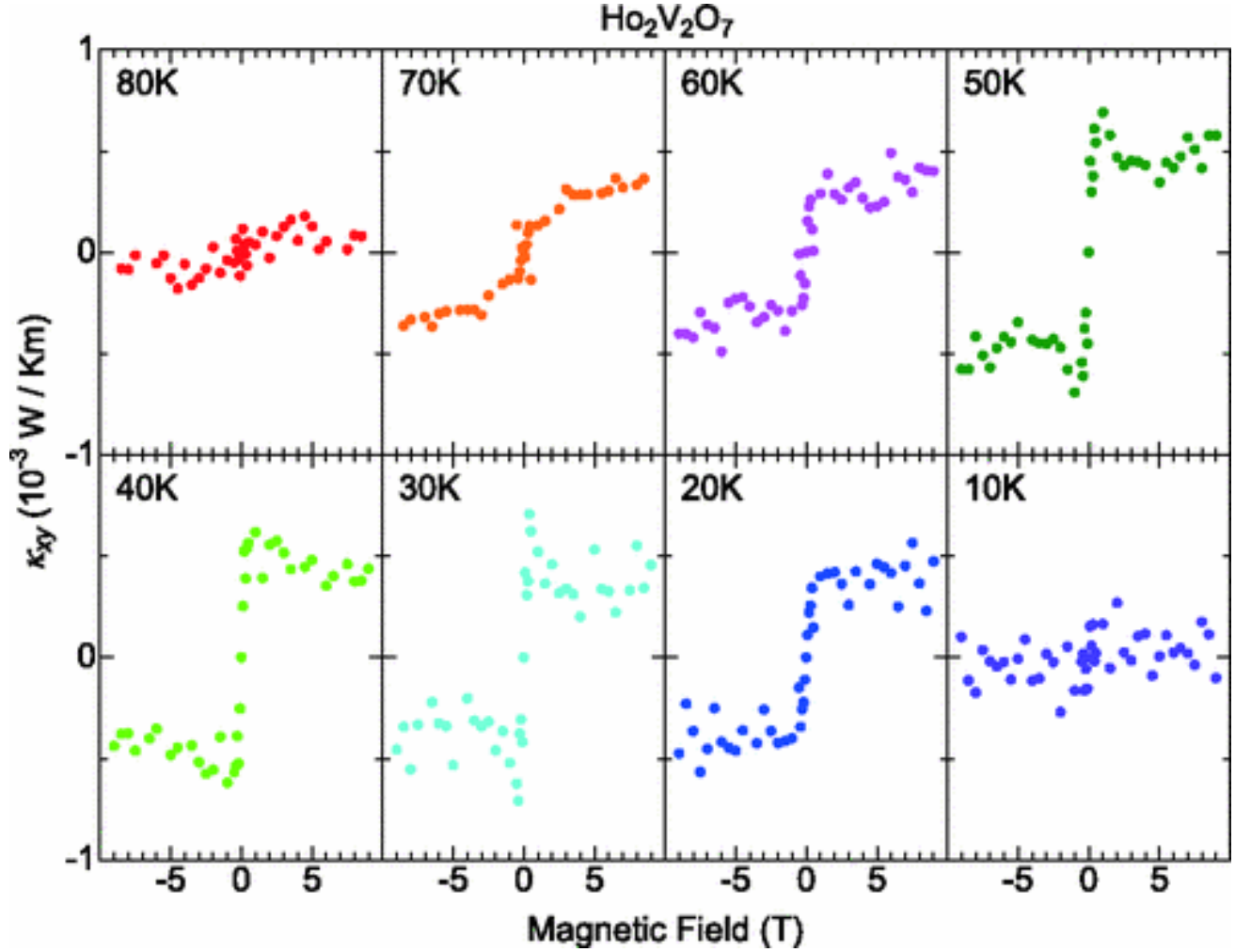

a
initial
$\mu_0 H_x$ off
10 μm
0.23 kOe
0.34 kOe
0.45 kOe
0.56 kOe
$\mu_0 H_x$ on
y
x
z

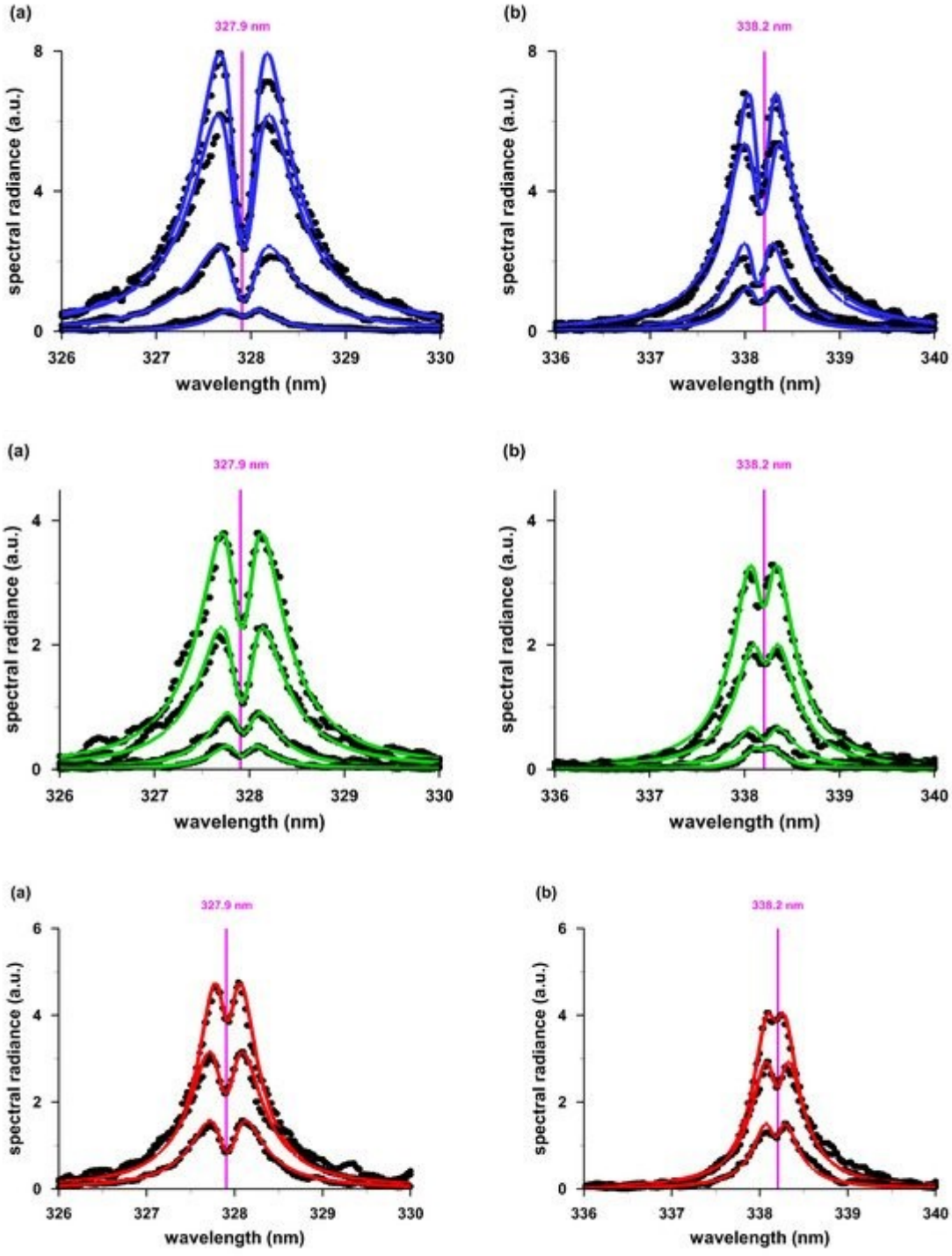

b
H_x
Stripe width
y
m
Δ_w
Domain wall
$\mu_0 H_k$ (kOe)
0.36
0.46
0.60
0.72
1.09
1.35
1.59
Stripe width (μm)
20
10
5
2
1
0
200
400
600
800
$\mu_0 H_x$ (Oe)

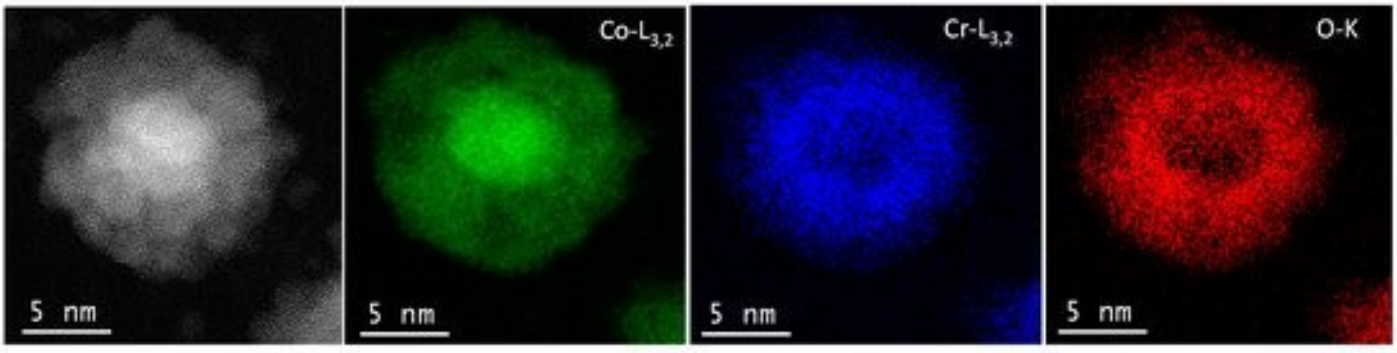

a
Observation
H_x
H_z
Ta
MgO
Ta
CoFeB
W
Substrate
b
Stripe domain
Bubble domain
c
←1.7 μm
Bubbles disappear
Stripes disappear
Global minimum:
Bubble
Stripe
$\mu_0 H_z$ (Oe)
λ_0 (μm)
d
$\mu_0 H_z$ 0 Oe
6.5 Oe
11. Oe
15.0 Oe
17.1 Oe
13.6 Oe
11.4 Oe
9.3 Oe
0 Oe
e
$\mu_0 H_z$ 0 Oe
2.2 Oe
5.0 Oe
12.1 Oe
12.9 Oe
7.9 Oe
5.0 Oe
3.6 Oe
0 Oe

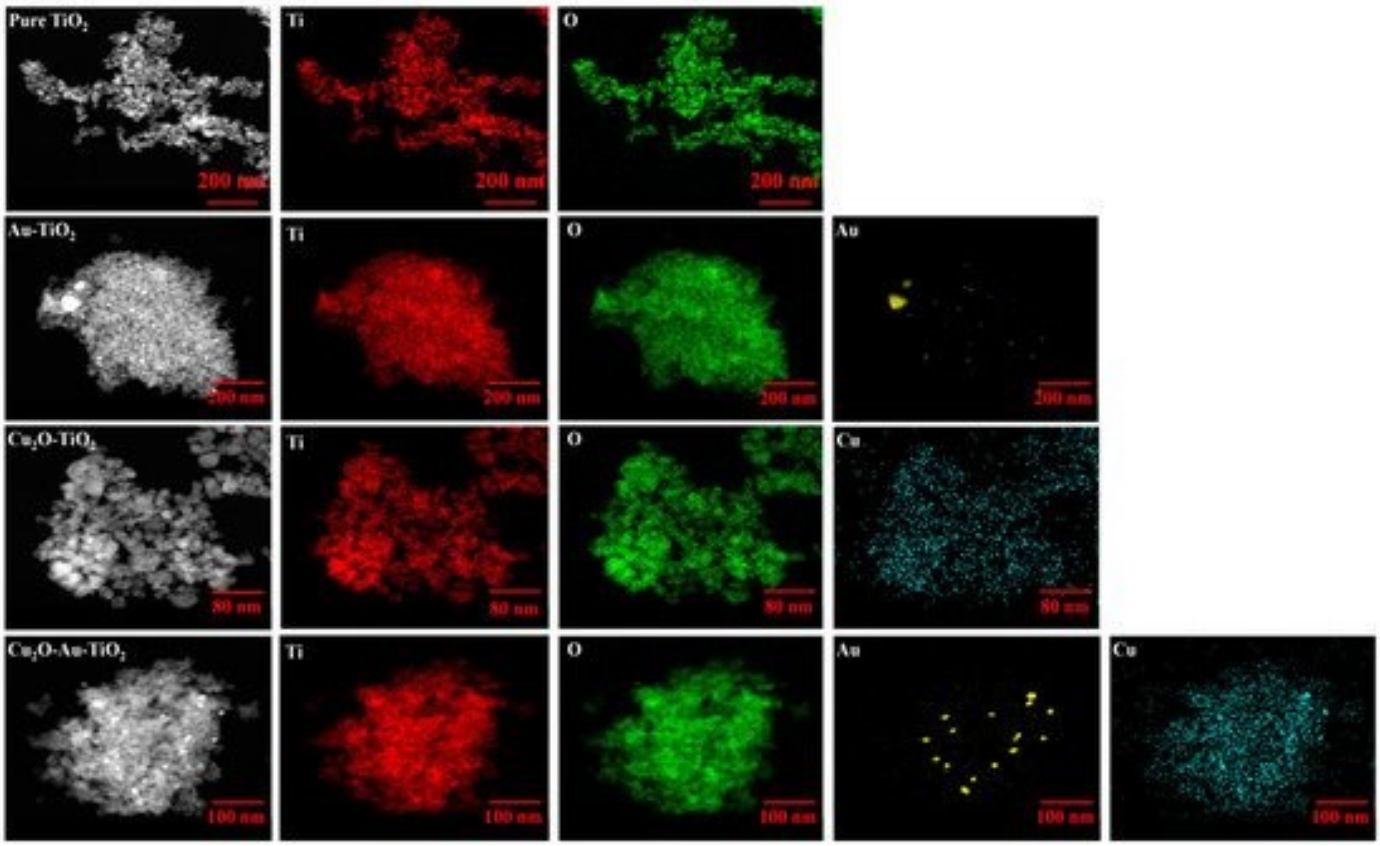

(a)
Pt
Gd
Co
Pt
Ta
Sub.
S/Pt
Pt
Co
Gd
Co
Pt
Ta
Sub.
D/Pt
Ta
Gd
Co
Pt
Ta
Sub.
S/Ta
Ta
Co
Gd
Co
Pt
Ta
Sub.
D/Ta
(b)
Kerr Rotation
Field (mT)
S/Pt
D/Pt
S/Ta
D/Ta
(c)
Moment (x10^{-4} A)
Temperature (K)
$T_{comp.}$ = 152 K
$T_{comp.}$ = 276 K
$T_{comp.}$ = 177 K
$T_{comp.}$ >300K
S/Pt
D/Pt
S/Ta
D/Ta
c)
CO2 (0.5, Morgan) + N2 (0.5, Morgan)
Mean electron energy, eV
Reduced electric field, Td
d)
CO2 (0.5, Morgan) + N2 (0.5, Morgan)
EEDF anisotropy
Electron energy, eV

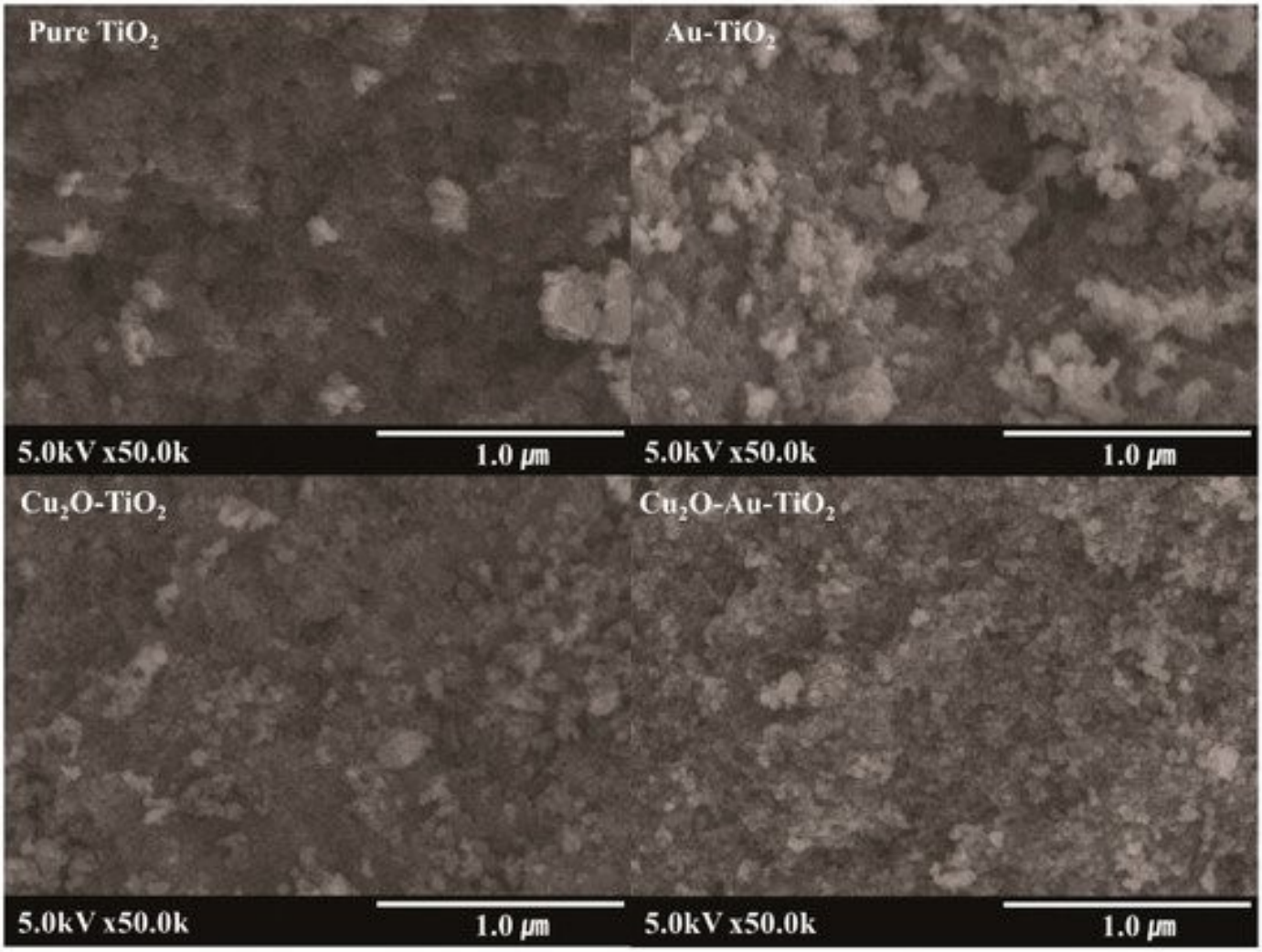

Lu2V2O7 H || [100]
80K
70K
60K
50K
40K
30K
20K
10K
κxy (10-3 W / Km)
Magnetic Field (T)

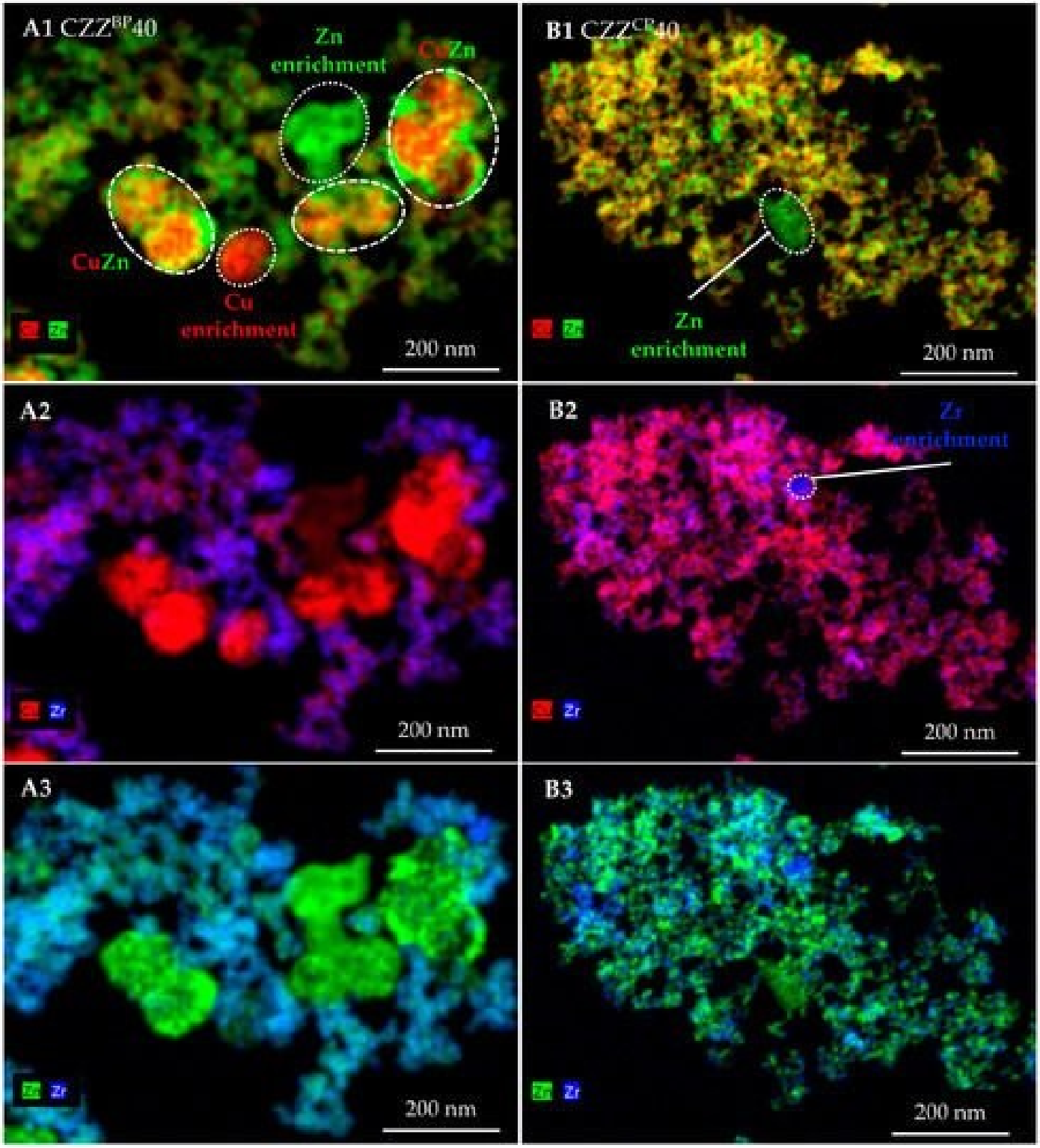

Ho2V2O7
80K
70K
60K
50K
40K
30K
20K
10K
κxy (10-3 W / Km)
Magnetic Field (T)

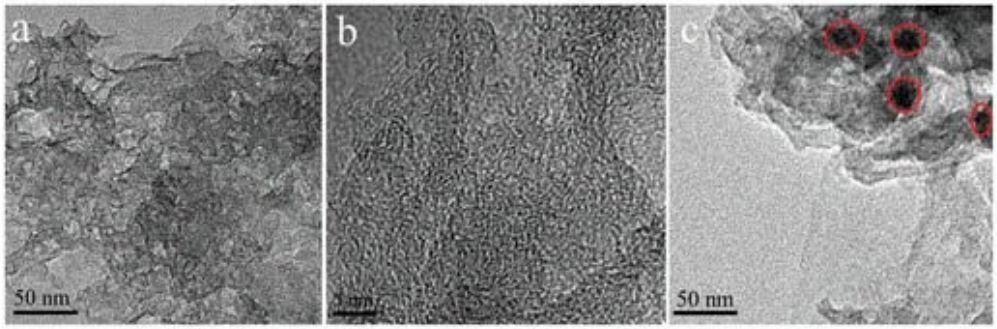

(a)
327.9 nm
spectral radiance (a.u.)
wavelength (nm)
(b)
338.2 nm
spectral radiance (a.u.)
wavelength (nm)
(a)
327.9 nm
spectral radiance (a.u.)
wavelength (nm)
(b)
338.2 nm
spectral radiance (a.u.)
wavelength (nm)
(a)
327.9 nm
spectral radiance (a.u.)
wavelength (nm)
(b)
338.2 nm
spectral radiance (a.u.)
wavelength (nm)

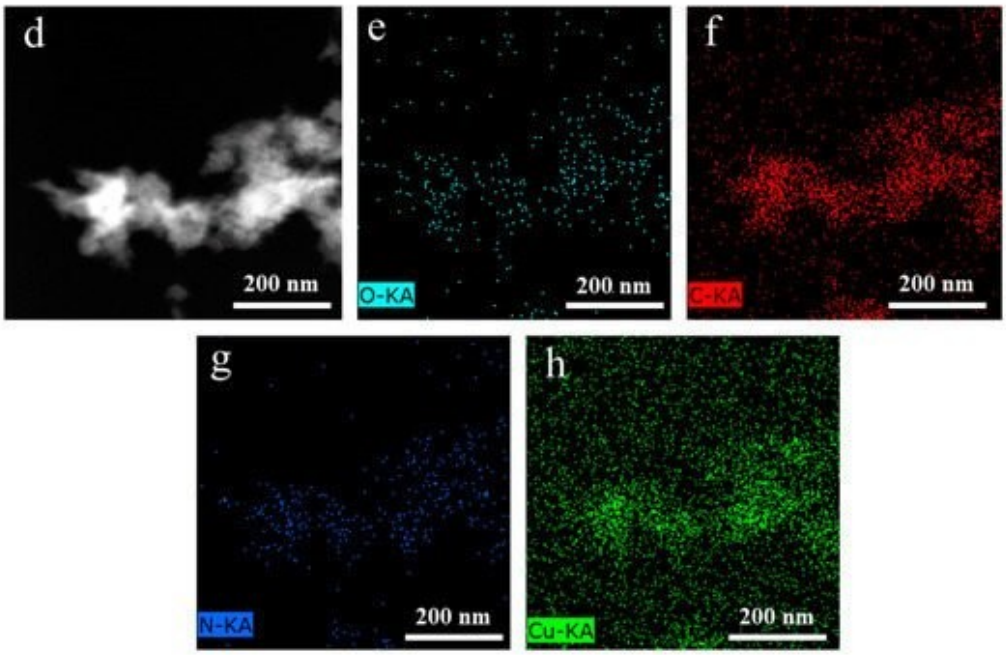

5 nm
Co-L3,2
5 nm
Cr-L3,2
5 nm
O-K
5 nm

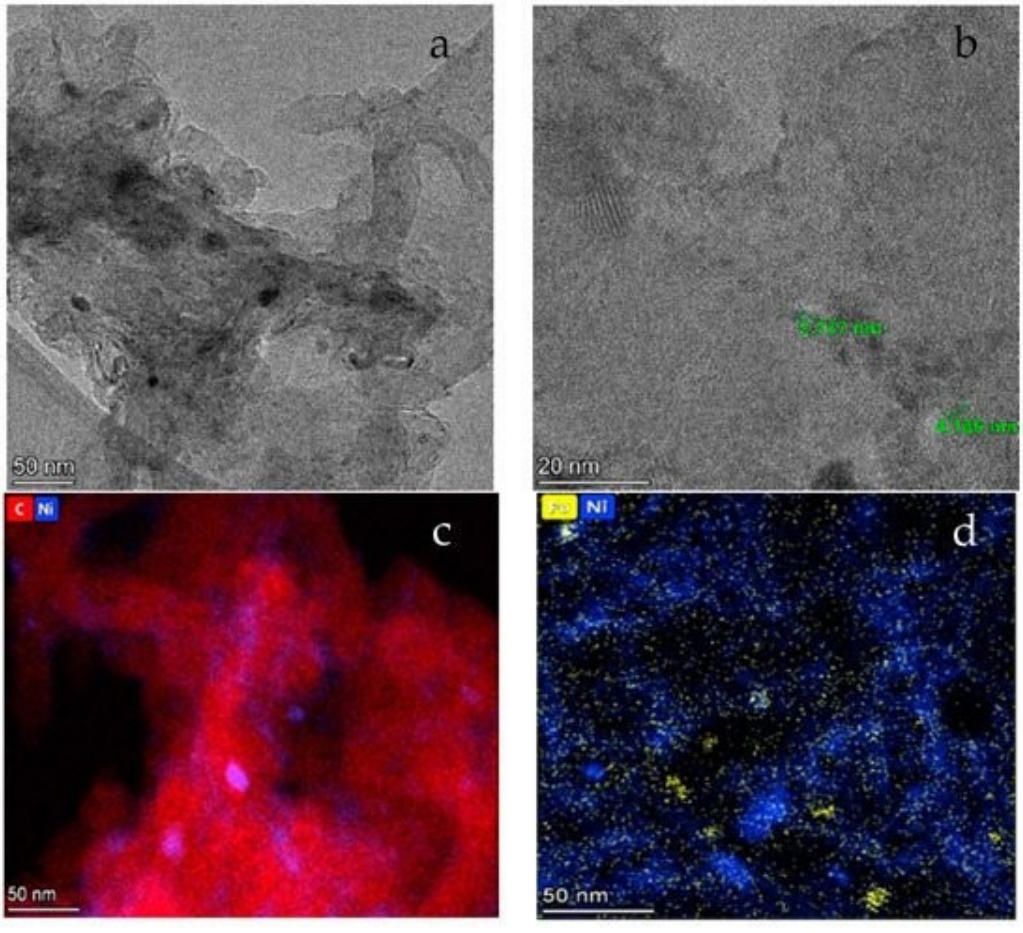

Pure TiO2
Ti
O
200 nm
Au-TiO2
Au
Cu2O-TiO2
Cu
80 nm
Cu2O-Au-TiO2
100 nm

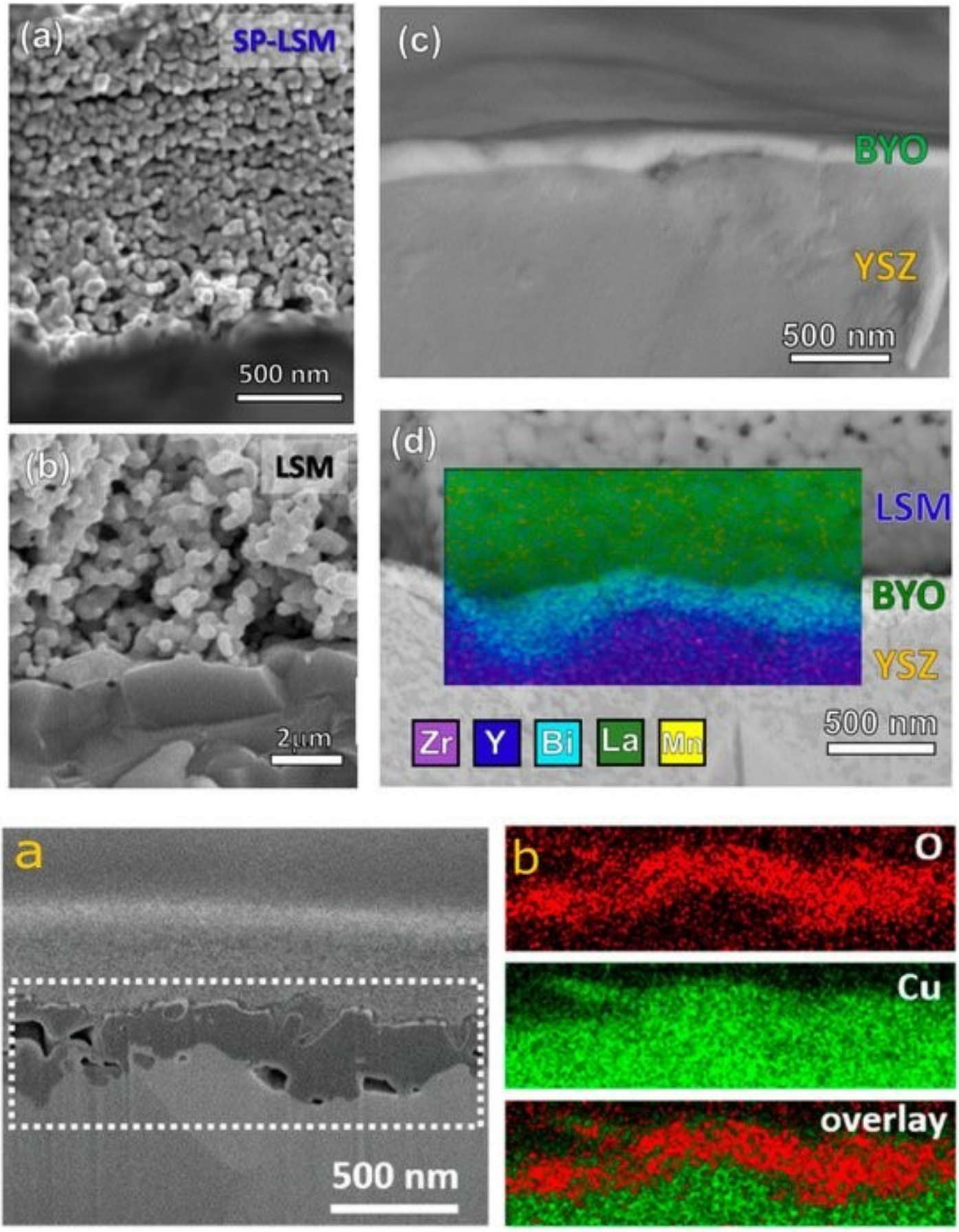

Pure TiO2
Au-TiO2
Cu2O-TiO2
Cu2O-Au-TiO2
5.0kV x50.0k
1.0 μm

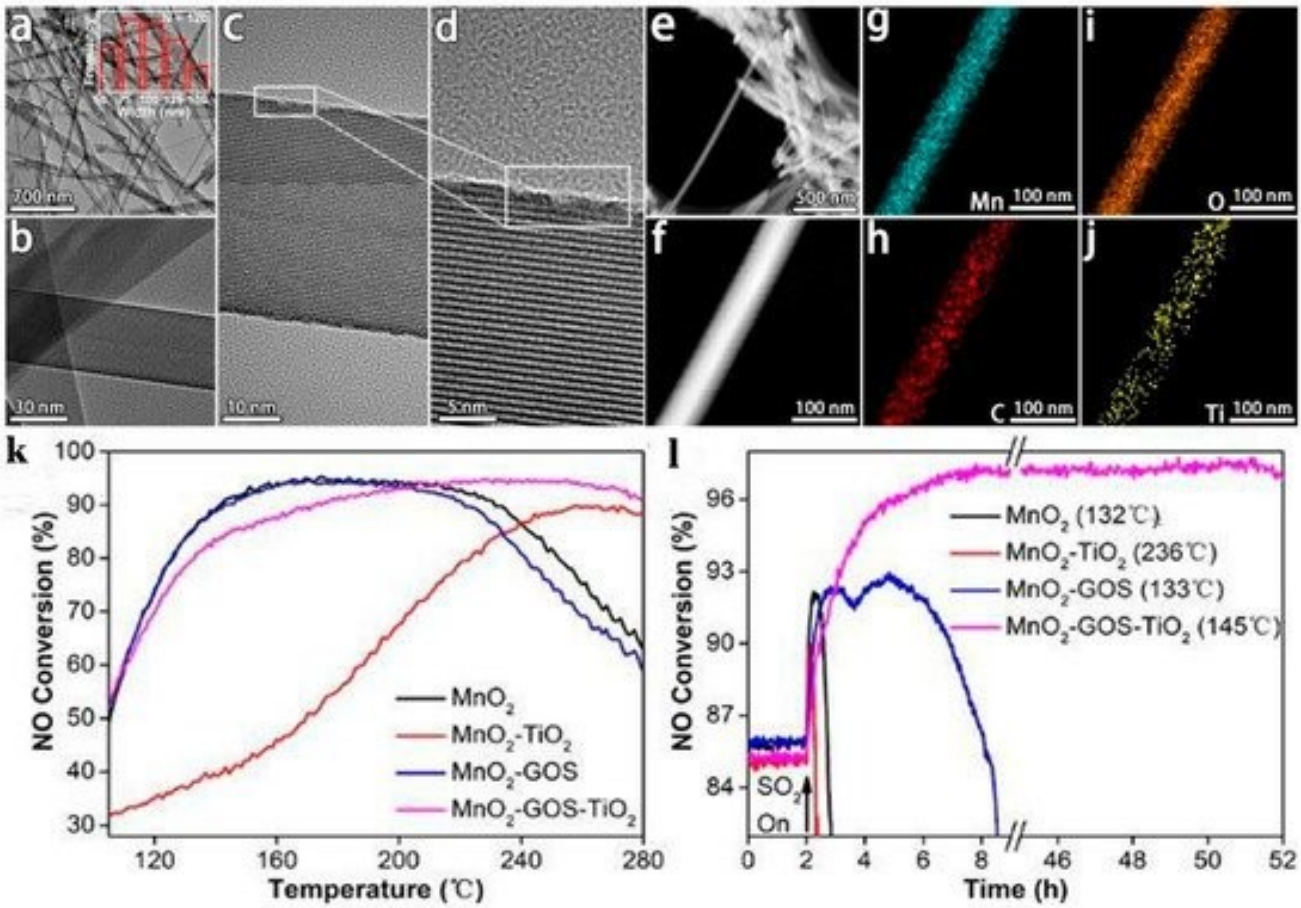

A1 CZZ^BP40
Zn enrichment
CuZn
CuZn
Cu enrichment
Cu
Zr
200 nm
B1 CZZ^CP40
Zn enrichment
Cu
Zr
200 nm
A2
Cu
Zr
200 nm
B2
Zr enrichment
Cu
Zr
200 nm
A3
Cu
Zr
200 nm
B3
Cu
Zr
200 nm

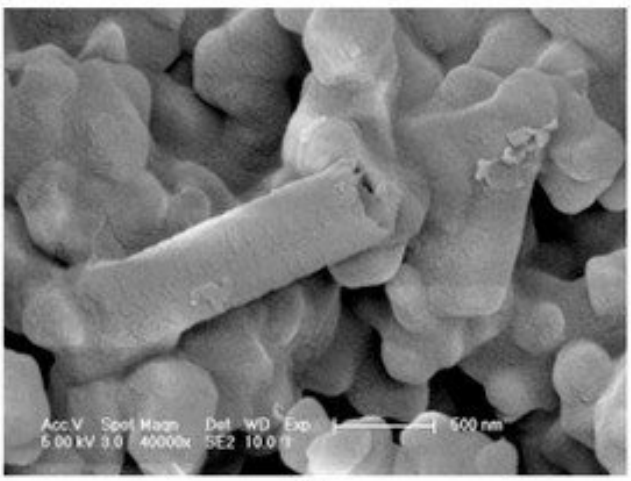

a
50 nm
b
c
50 nm


d
200 nm
e
O-KA
200 nm
f
C-KA
200 nm
g
N-KA
200 nm
h
Cu-KA
200 nm

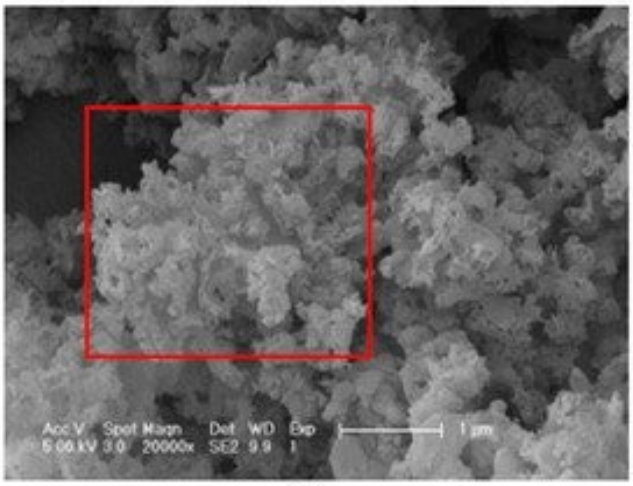

a
50 nm
b
20 nm
C Ni
c
50 nm
Ni
d
50 nm


(a)
SP-LSM
500 nm
(b)
LSM
2μm
(c)
BYO
YSZ
500 nm
(d)
LSM
BYO
YSZ
Zr
Y
Bi
La
Mn
500 nm
a
500 nm
b
O
Cu
overlay

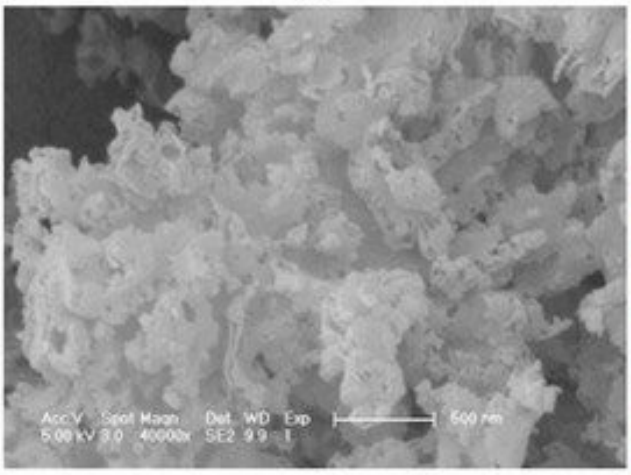

a
c
d
e
g
i
b
f
h
j
700 nm
10 nm
5 nm
500 nm
Mn 100 nm
O 100 nm
C 100 nm
Ti 100 nm
k
NO Conversion (%)
Temperature (℃)
MnO2
MnO2-TiO2
MnO2-GOS
MnO2-GOS-TiO2
l
NO Conversion (%)
Time (h)
MnO2 (132℃)
MnO2-TiO2 (236℃)
MnO2-GOS (133℃)
MnO2-GOS-TiO2 (145℃)
SO2
On


500 nm

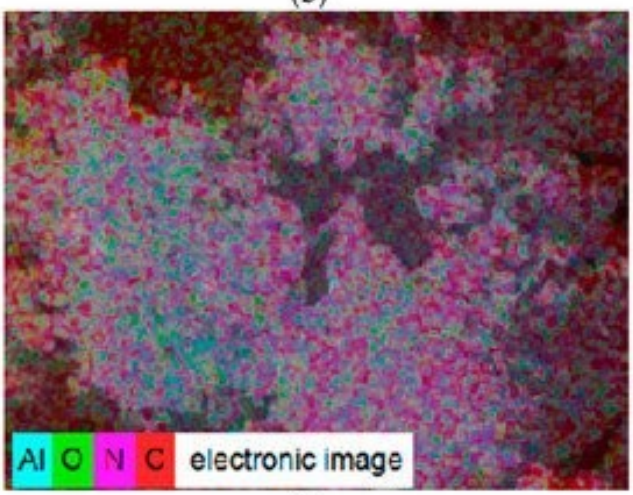
(a)


1 μm

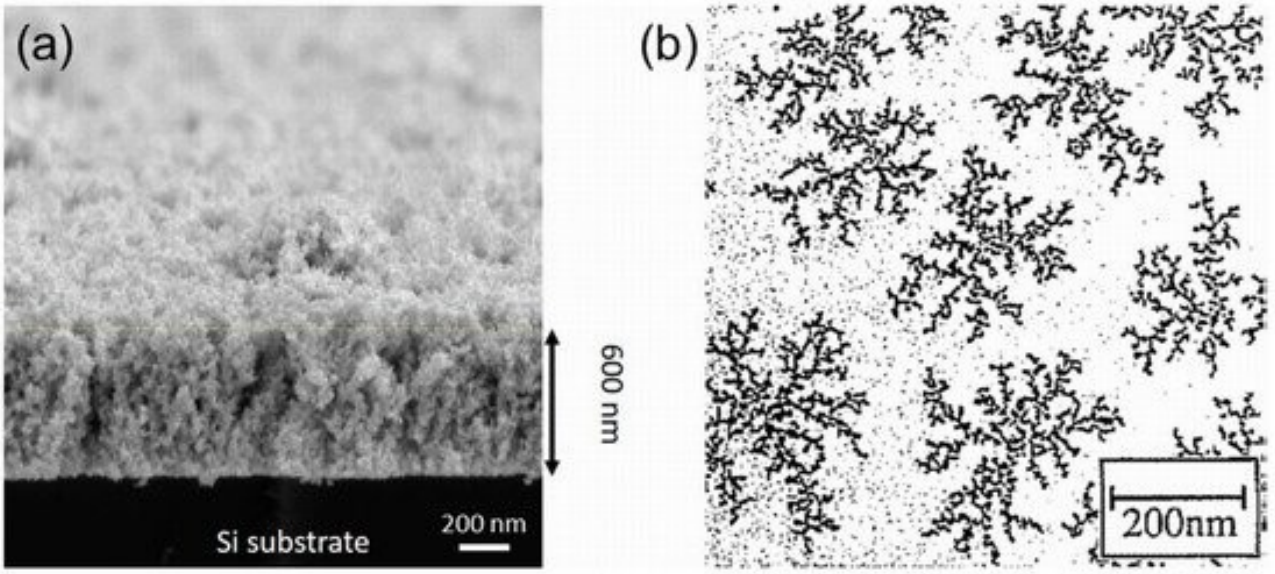
(b)

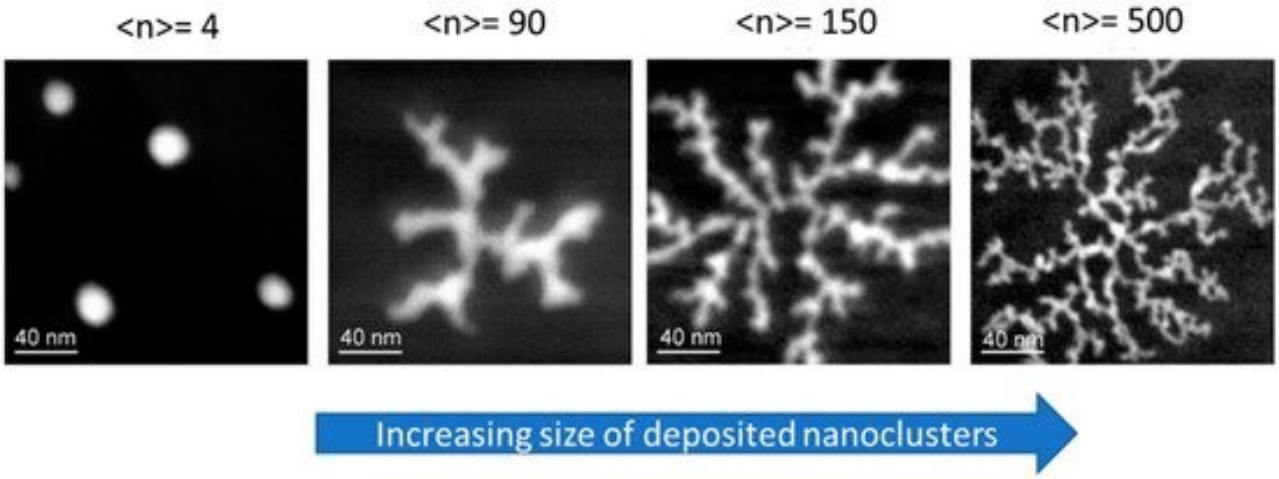

500 nm

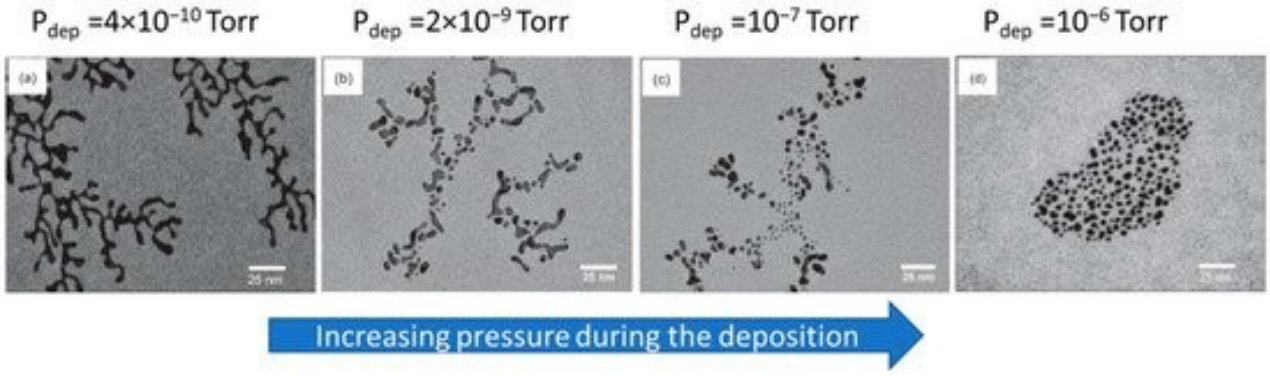
(c)

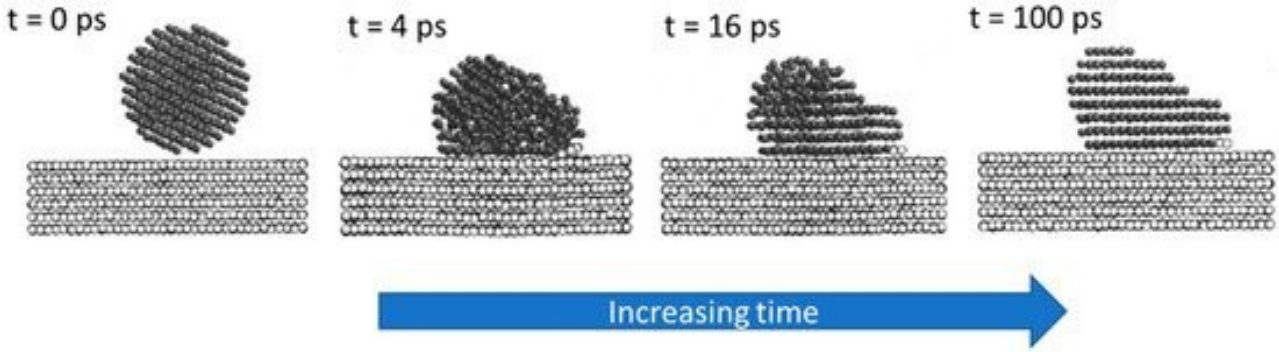

Al
O
N
C
electronic image

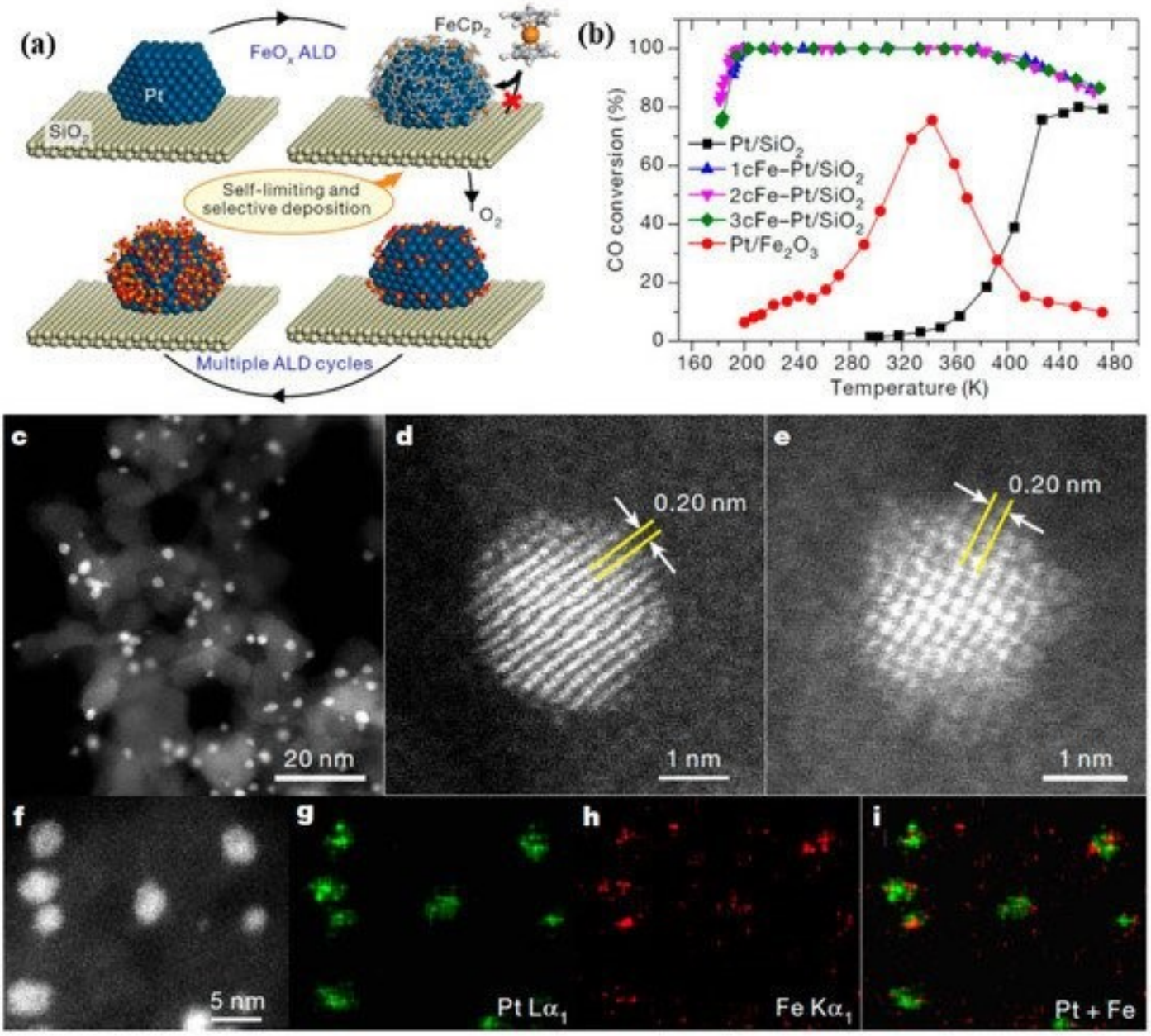
(d)

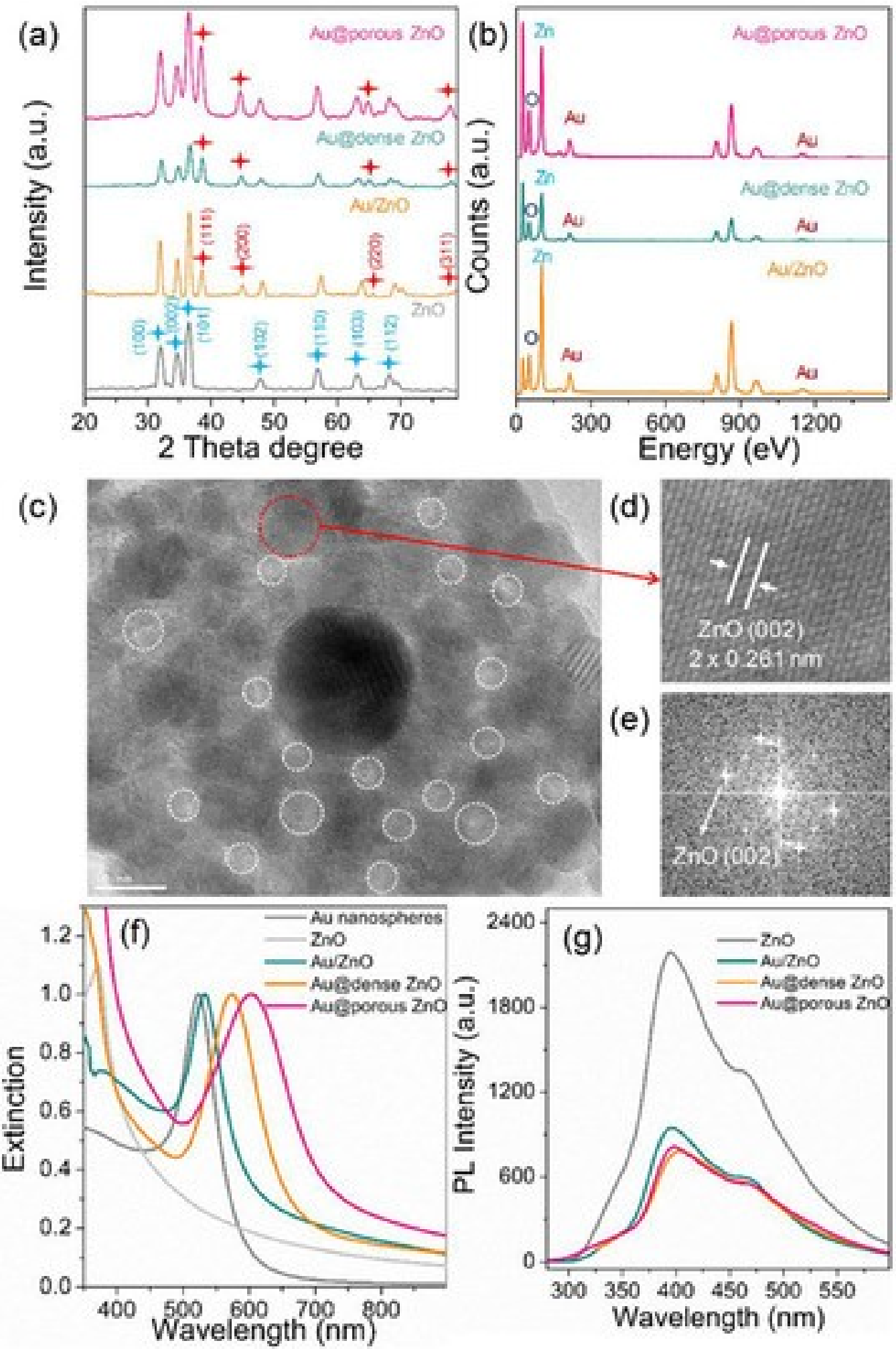

(a)
600 nm
Si substrate
200 nm
(b)
200nm

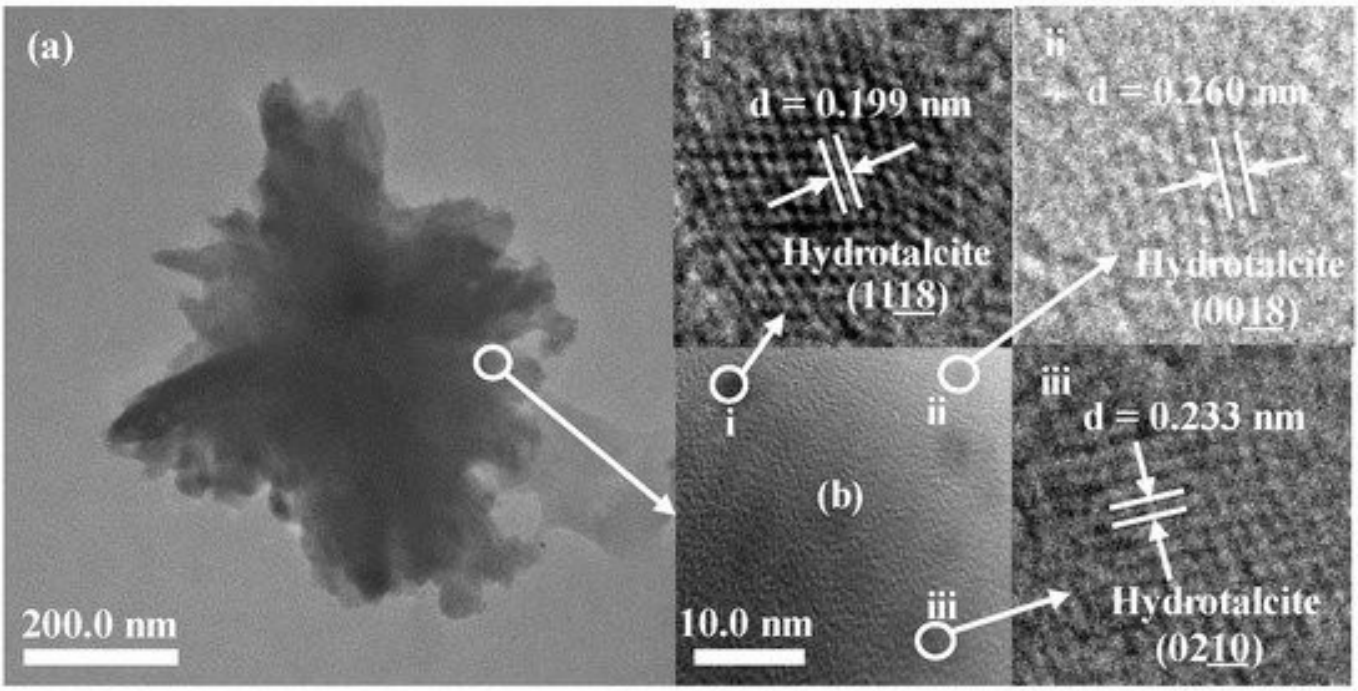

<n>= 4
<n>= 90
<n>= 150
<n>= 500
40 nm
40 nm
40 nm
40 nm
Increasing size of deposited nanoclusters

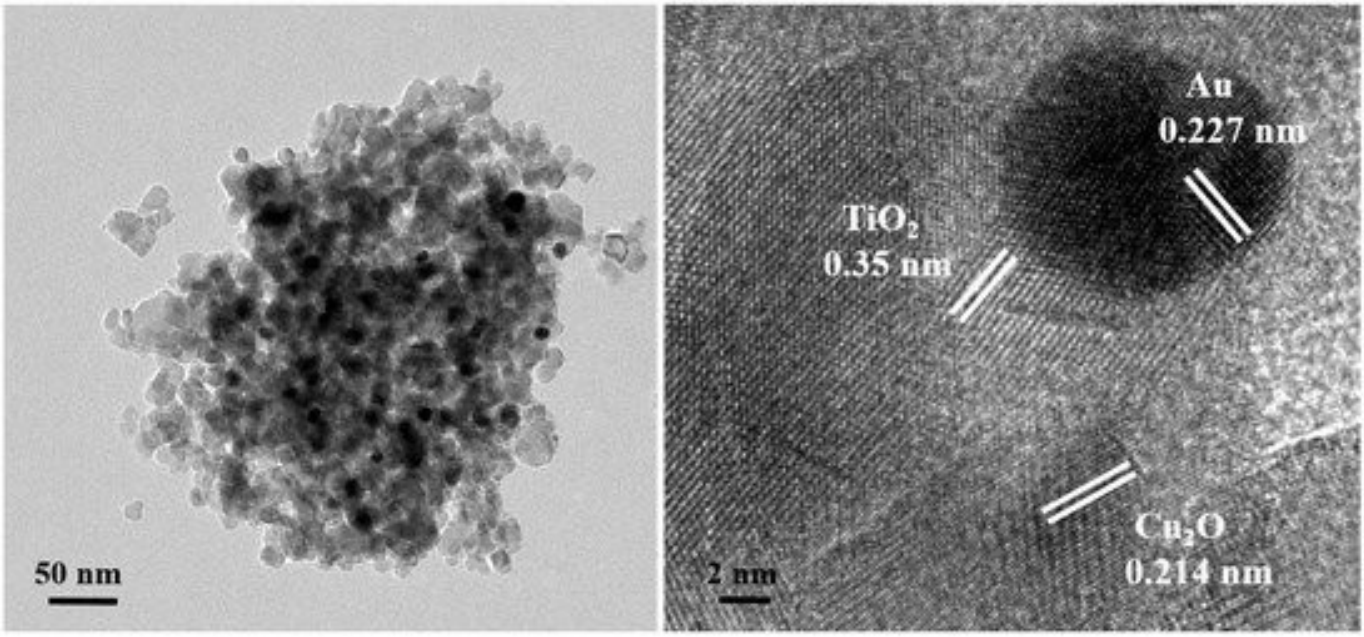

P dep =4×10-10 Torr
P dep =2×10-9 Torr
P dep =10-7 Torr
P dep =10-6 Torr
Increasing pressure during the deposition

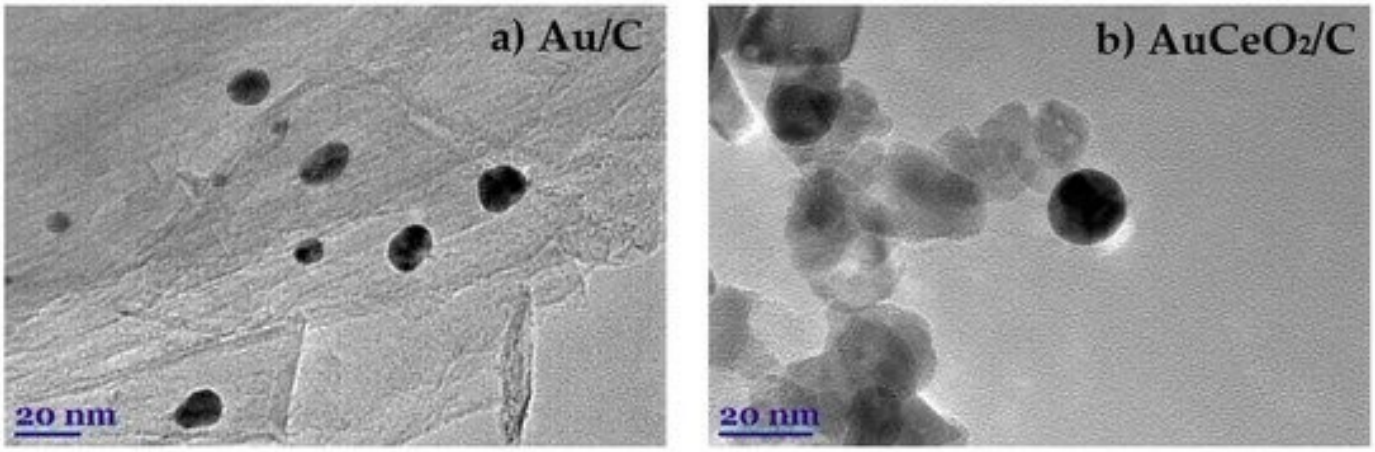

t = 0 ps
t = 4 ps
t = 16 ps
t = 100 ps
Increasing time

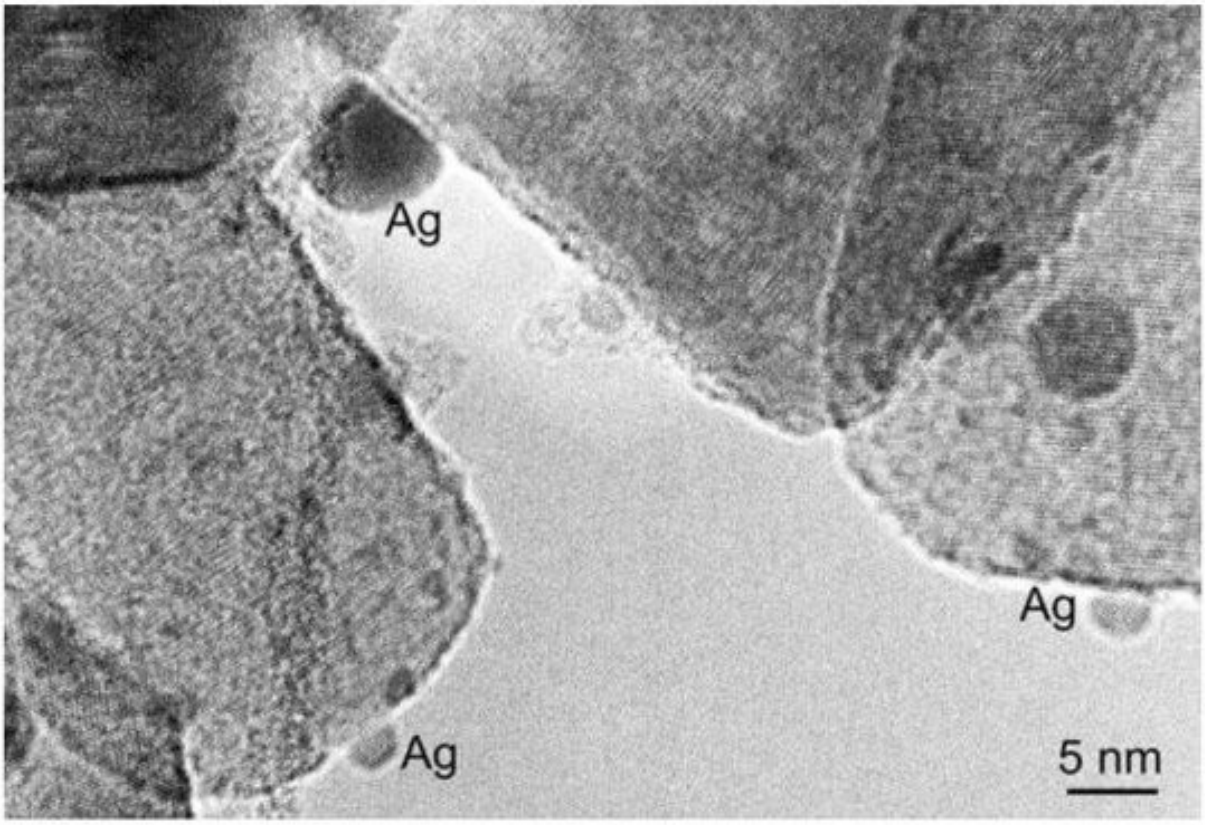

(a)
FeOx ALD
FeCp2
Pt
SiO2
Self-limiting and selective deposition
O2
Multiple ALD cycles
(b)
CO conversion (%)
Temperature (K)
Pt/SiO2
1cFe-Pt/SiO2
2cFe-Pt/SiO2
3cFe-Pt/SiO2
Pt/Fe2O3
c
20 nm
d
0.20 nm
1 nm
e
0.20 nm
1 nm
f
5 nm
g
Pt Lα1
h
Fe Kα1
i
Pt + Fe

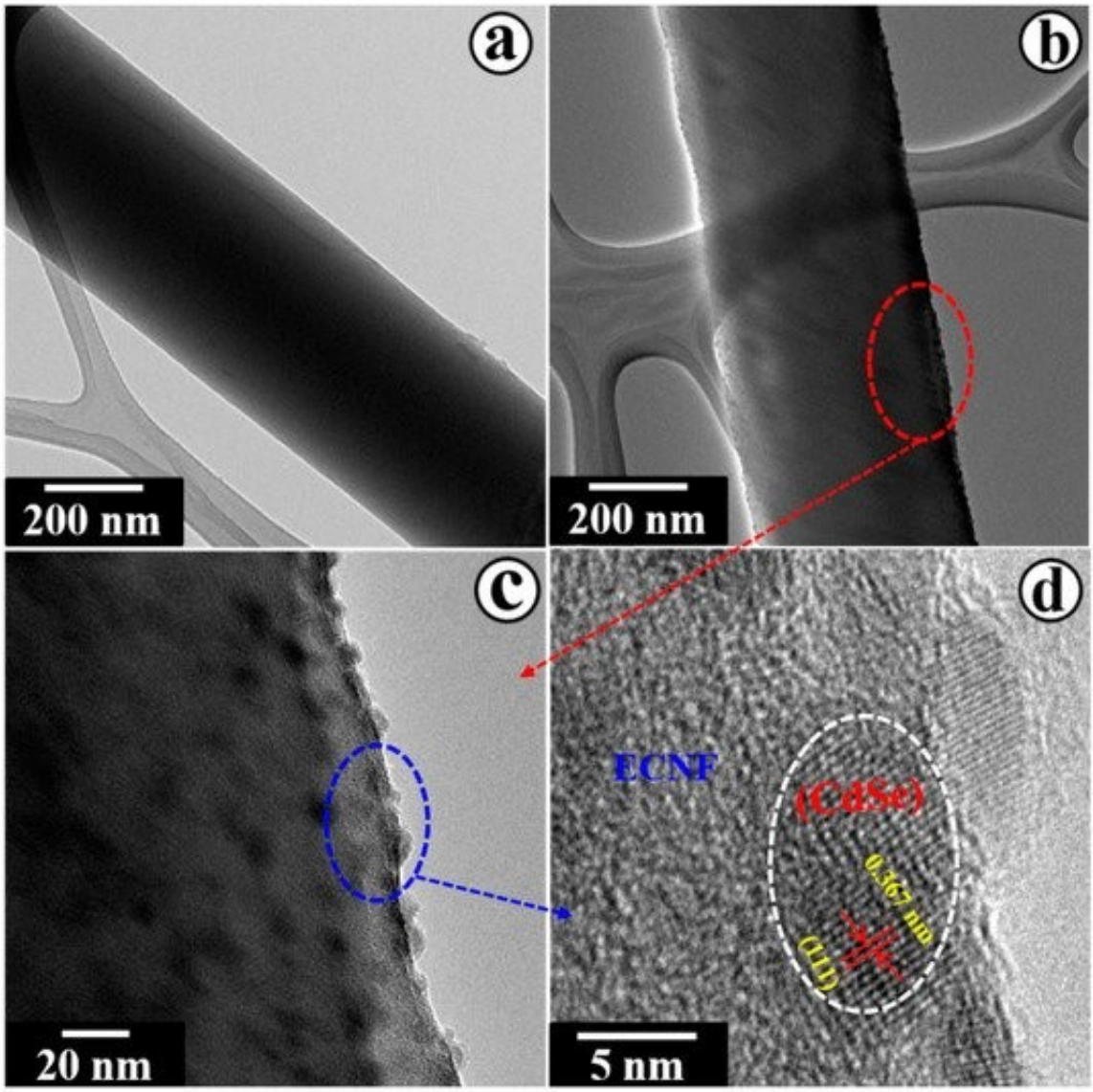

(a)
Au@porous ZnO
Au@dense ZnO
Au/ZnO
ZnO
Intensity (a.u.)
2 Theta degree
(b)
Zn
O
Au
Counts (a.u.)
Energy (eV)
(c)
(d)
ZnO (002)
2 x 0.261 nm
(e)
ZnO (002)
(f)
Au nanospheres
ZnO
Au/ZnO
Au@dense ZnO
Au@porous ZnO
Extinction
Wavelength (nm)
(g)
PL Intensity (a.u.)
Wavelength (nm)

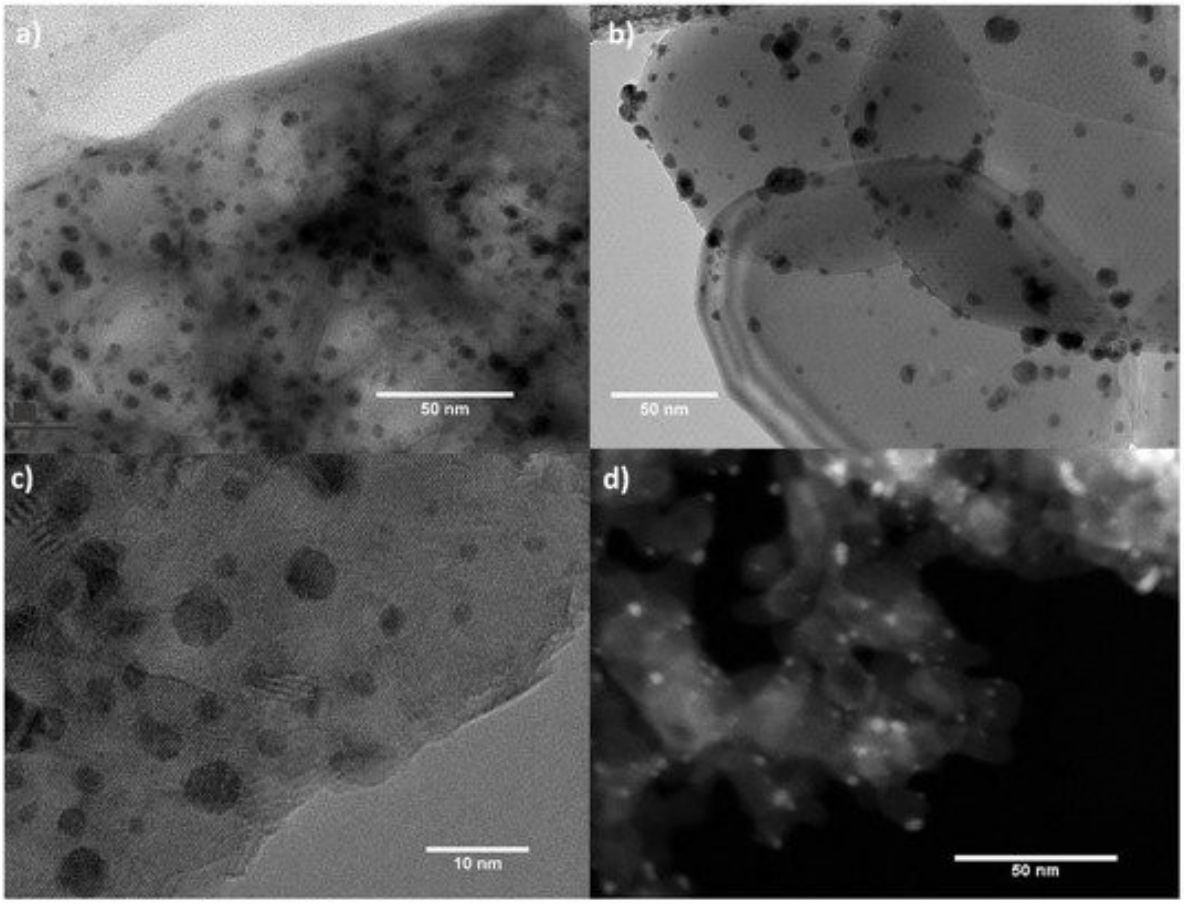

(a)
200.0 nm
i
d = 0.199 nm
Hydrotalcite
(1118)
ii
d = 0.260 nm
Hydrotalcite
(0018)
i
ii
(b)
10.0 nm
iii
iii
d = 0.233 nm
Hydrotalcite
(0210)

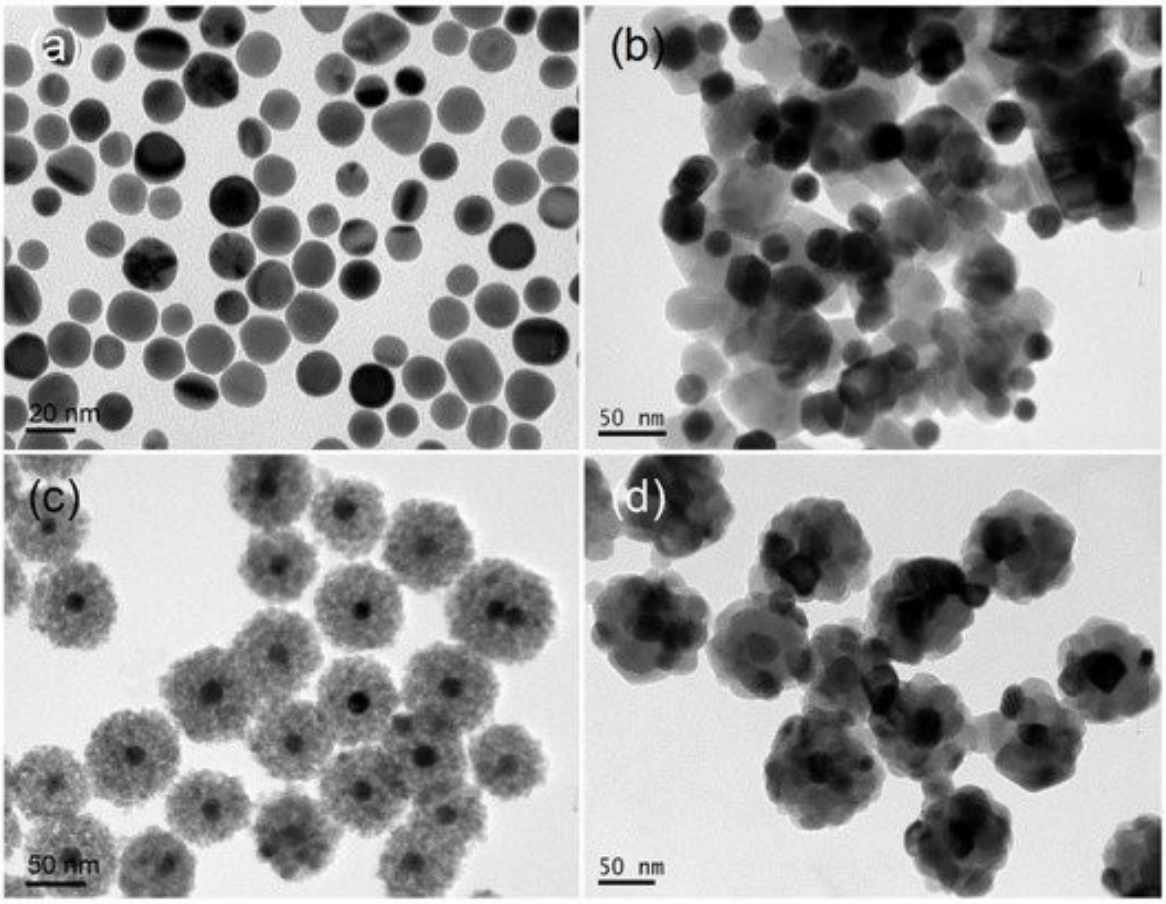

50 nm
Au
0.227 nm
TiO2
0.35 nm
Cu2O
0.214 nm
2 nm


a) Au/C
20 nm
b) AuCeO2/C
20 nm


Ag
Ag
Ag
5 nm

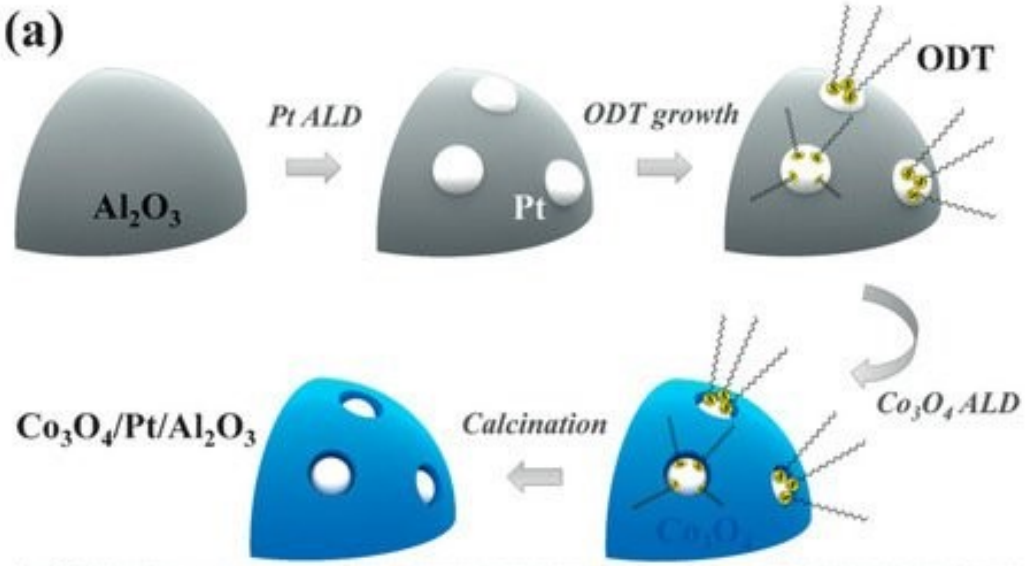

a
200 nm
b
200 nm
c
20 nm
d
ECNF
(CdSe)
0.367 nm
(111)
5 nm

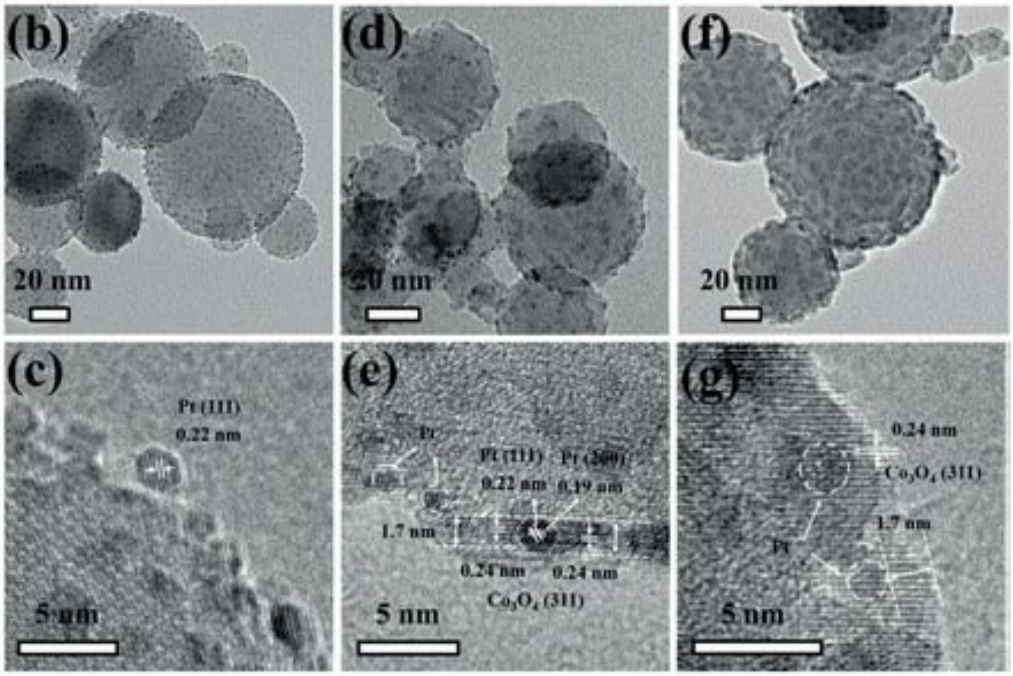

a)
50 nm
b)
50 nm
c)
10 nm
d)
50 nm

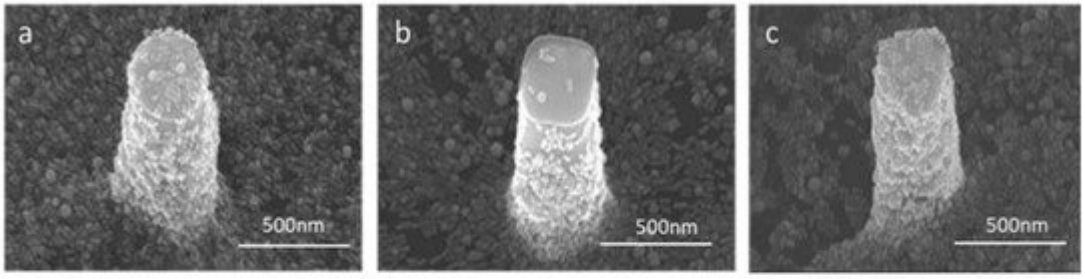

a)
20 nm
(b)
50 nm
(c)
50 nm
d)
50 nm

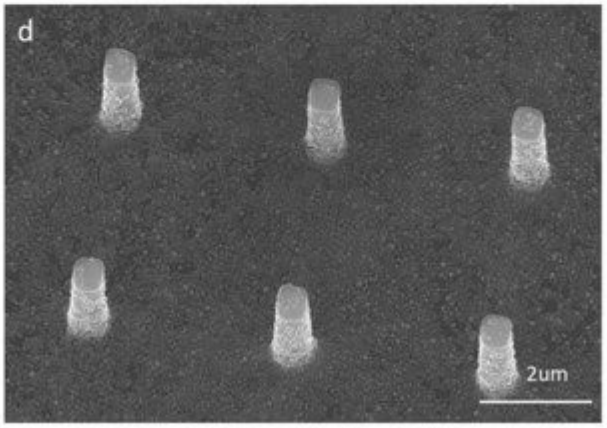
a)
HAuCl4
THPC
Au NP
(i)
(ii)
(iii)
MCM-41
Au-THPC
MCM-41-NH2
Au-MCM-41
b)
5 nm
c)
2 nm
d)
50 nm
e)
20 nm
f)
50 nm
g)
10 nm

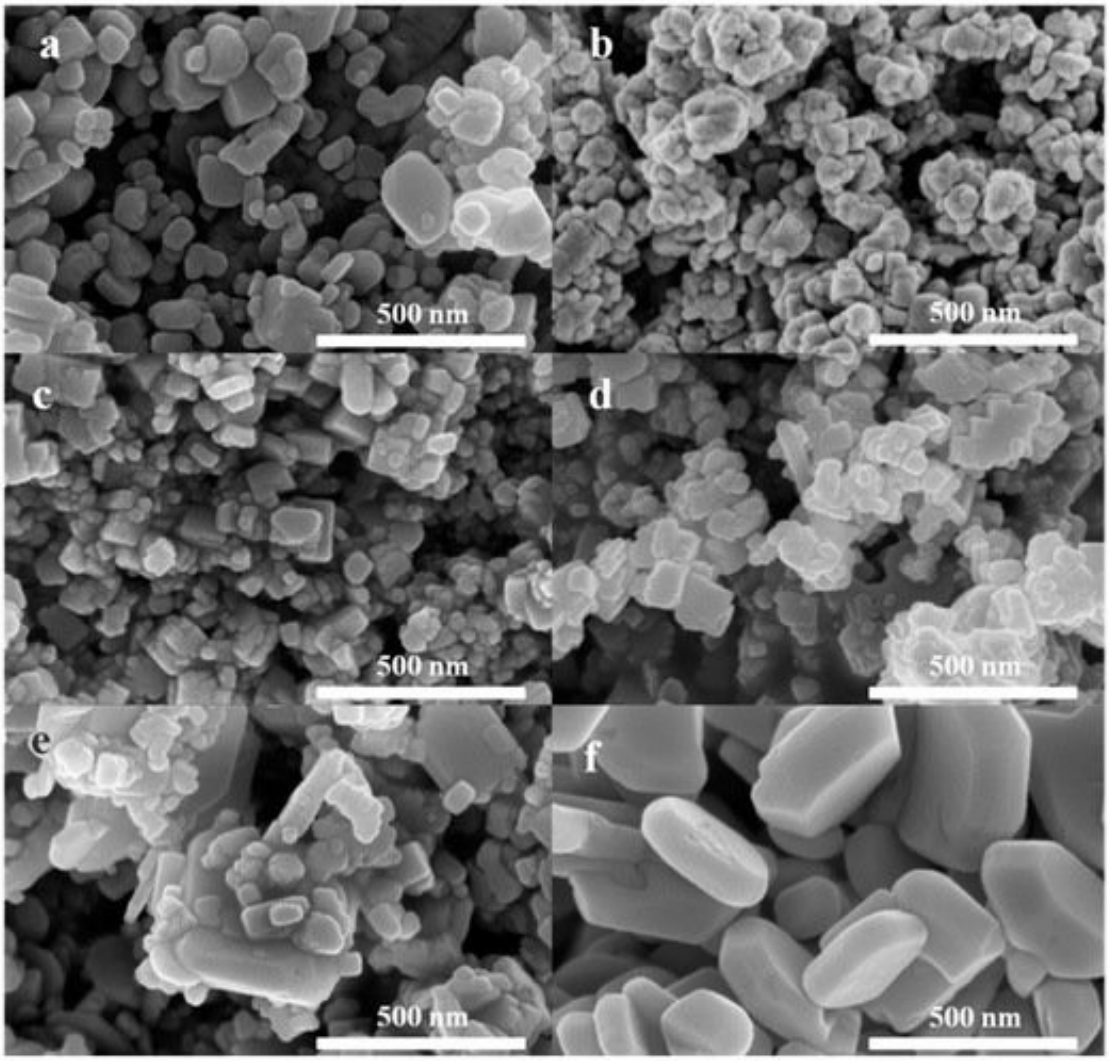
(a)
500 nm
(b)
100 nm
(c)
Ag
d111=2.3Å
CeO2
d111=3.1Å
Ag
d111=2.3Å
5 nm
(d)
20 nm

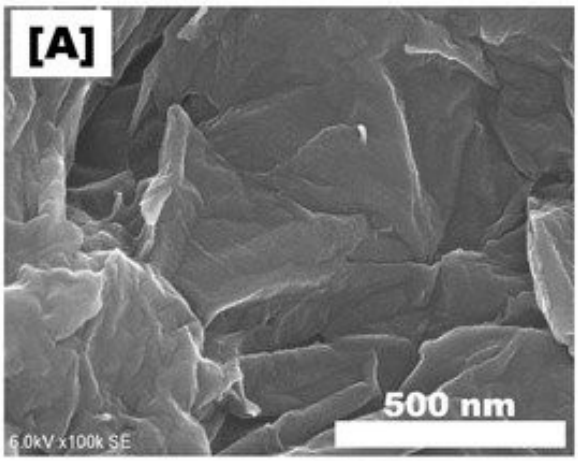

(a)
Al2O3
Pt ALD
Pt
ODT growth
ODT
Co3O4 ALD
Calcination
Co3O4/Pt/Al2O3

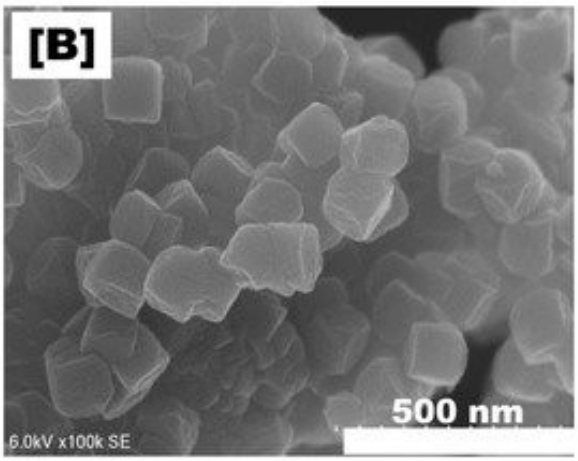

(b)
20 nm
(d)
20 nm
(f)
20 nm
(c)
Pt (111)
0.22 nm
5 nm
(e)
Pt
Pt (111)
0.22 nm
Pt (200)
0.19 nm
1.7 nm
0.24 nm
0.24 nm
Co3O4 (311)
5 nm
(g)
0.24 nm
Co3O4 (311)
1.7 nm
Pt
5 nm

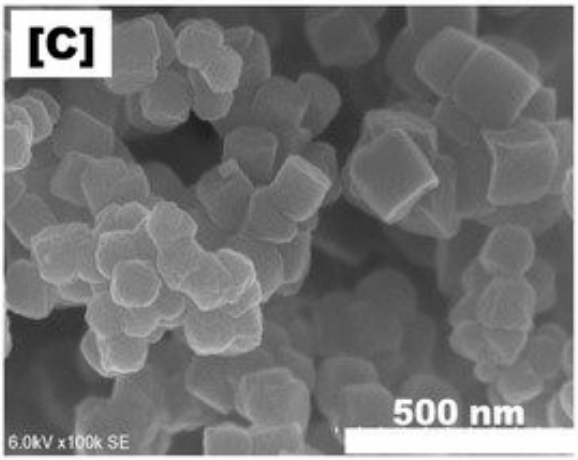

a
500nm
b
500nm
c
500nm

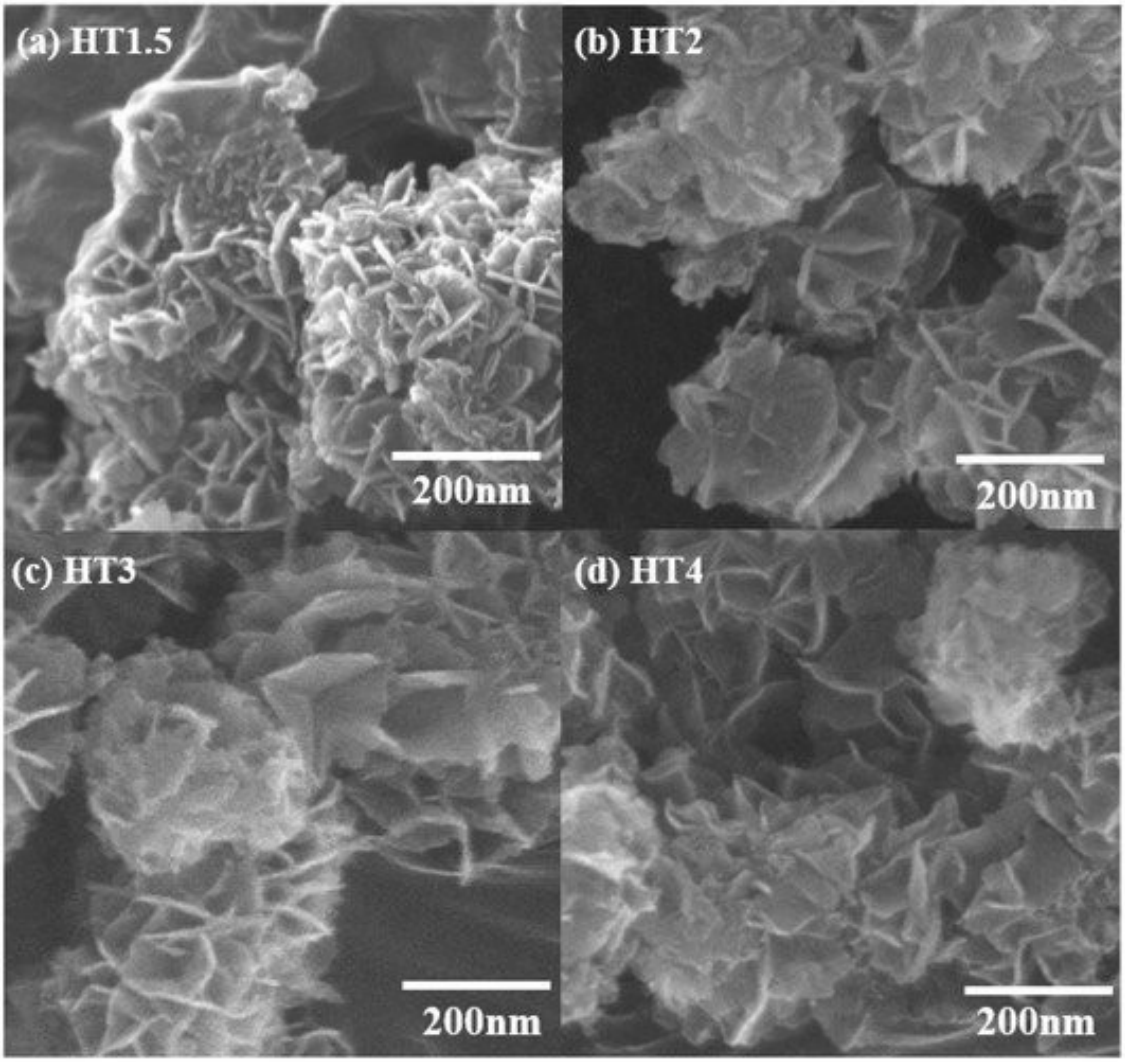

d
2um

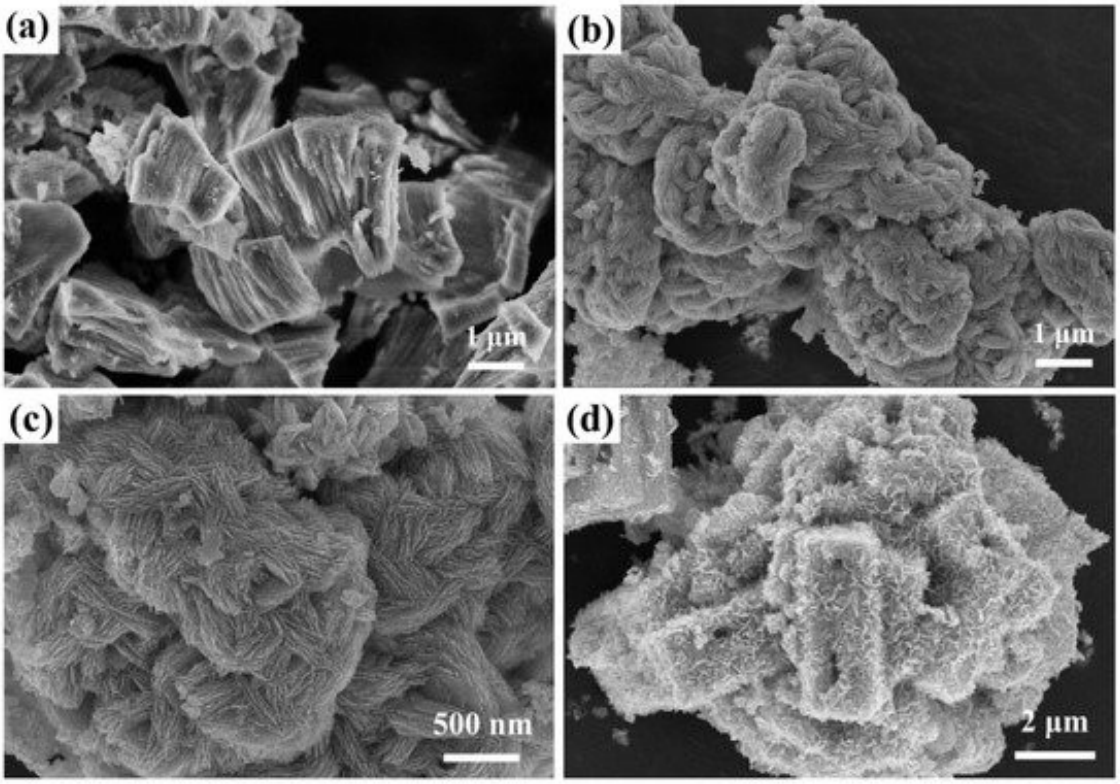

a
500 nm
b
500 nm
c
500 nm
d
500 nm
e
500 nm
f
500 nm

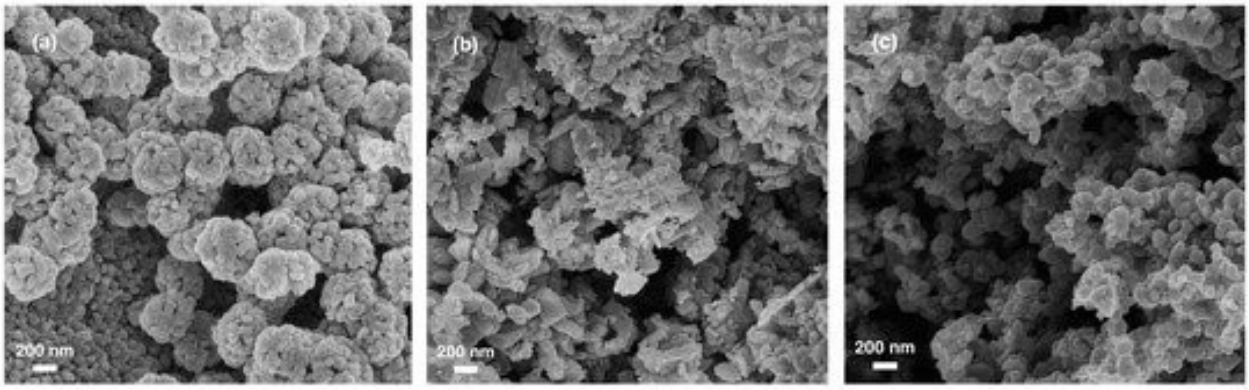

[A]
500 nm
6.0kV x100k SE

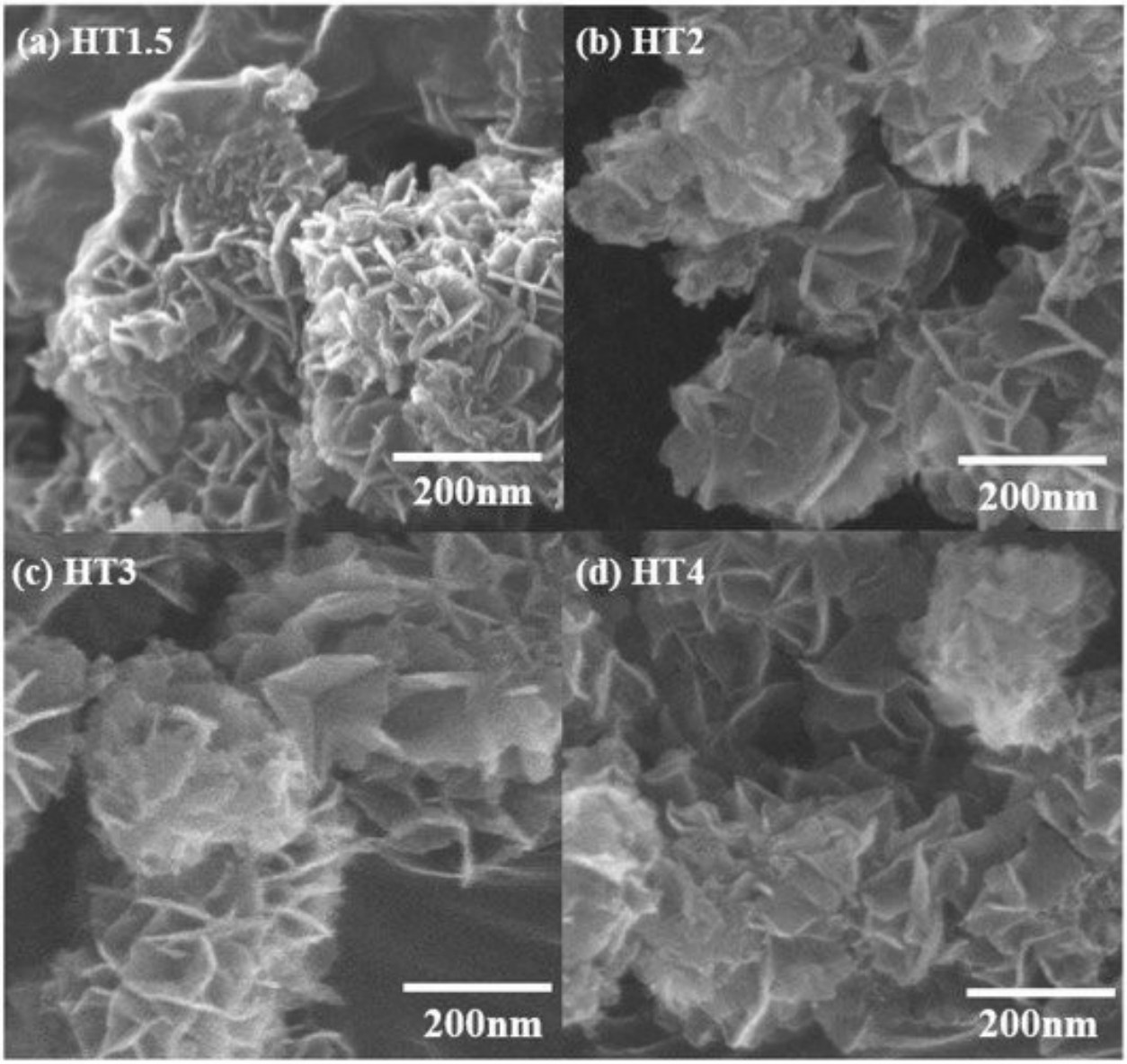

[B]
500 nm
6.0kV x100k SE

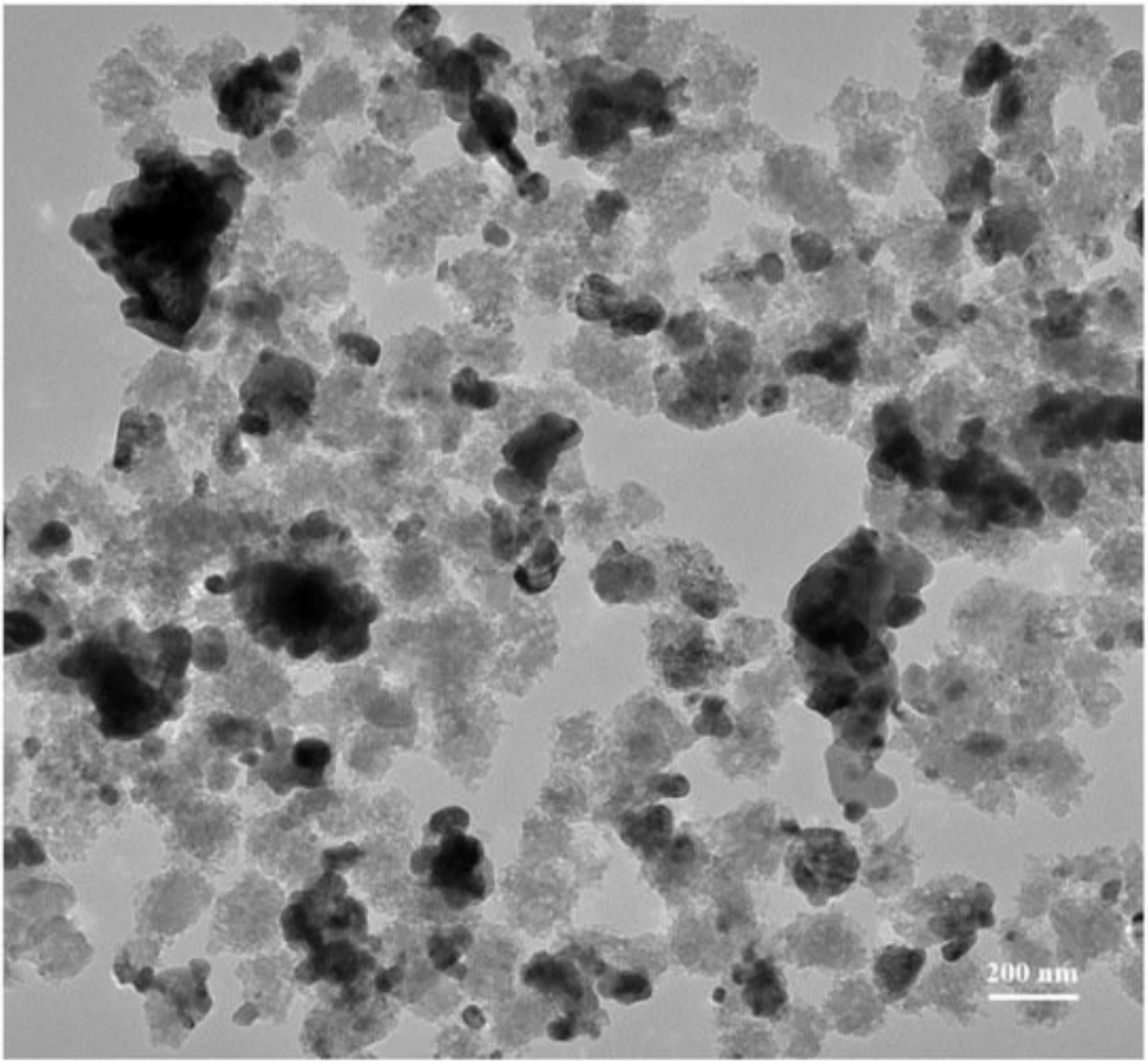

[C]
500 nm
6.0kV x100k SE

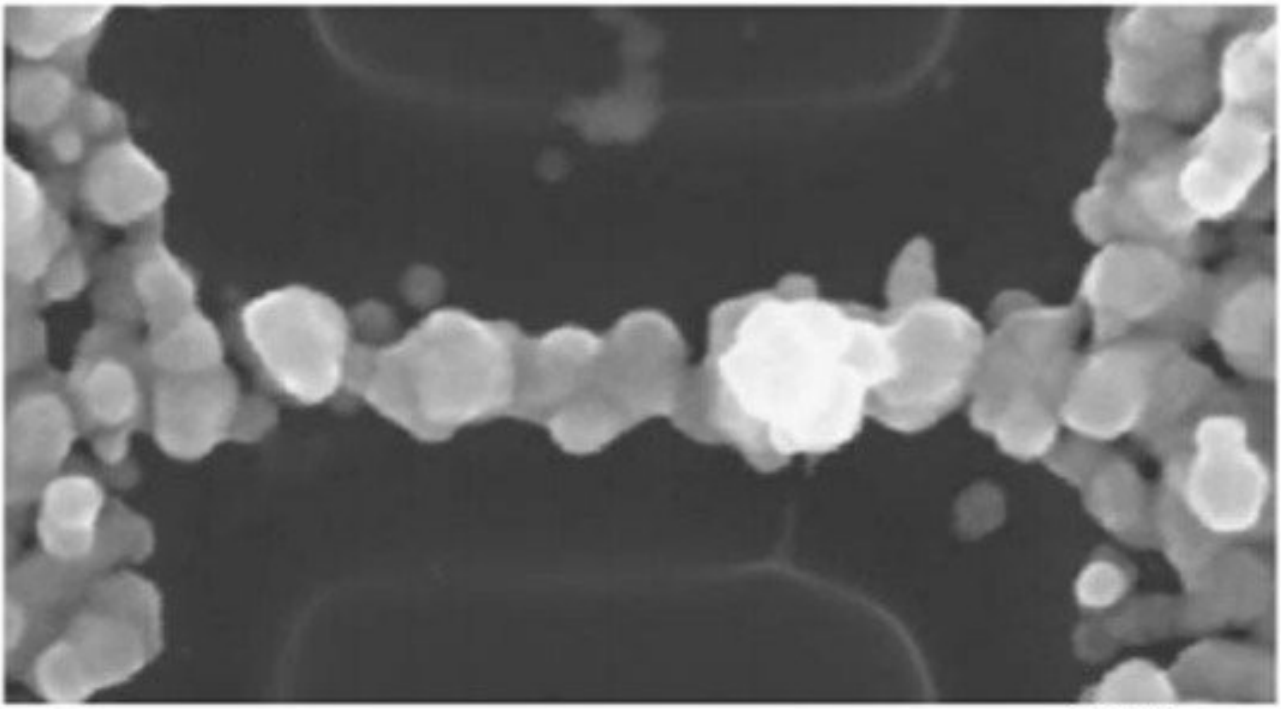

(a) HT1.5
200nm
(b) HT2
200nm
(c) HT3
200nm
(d) HT4
200nm

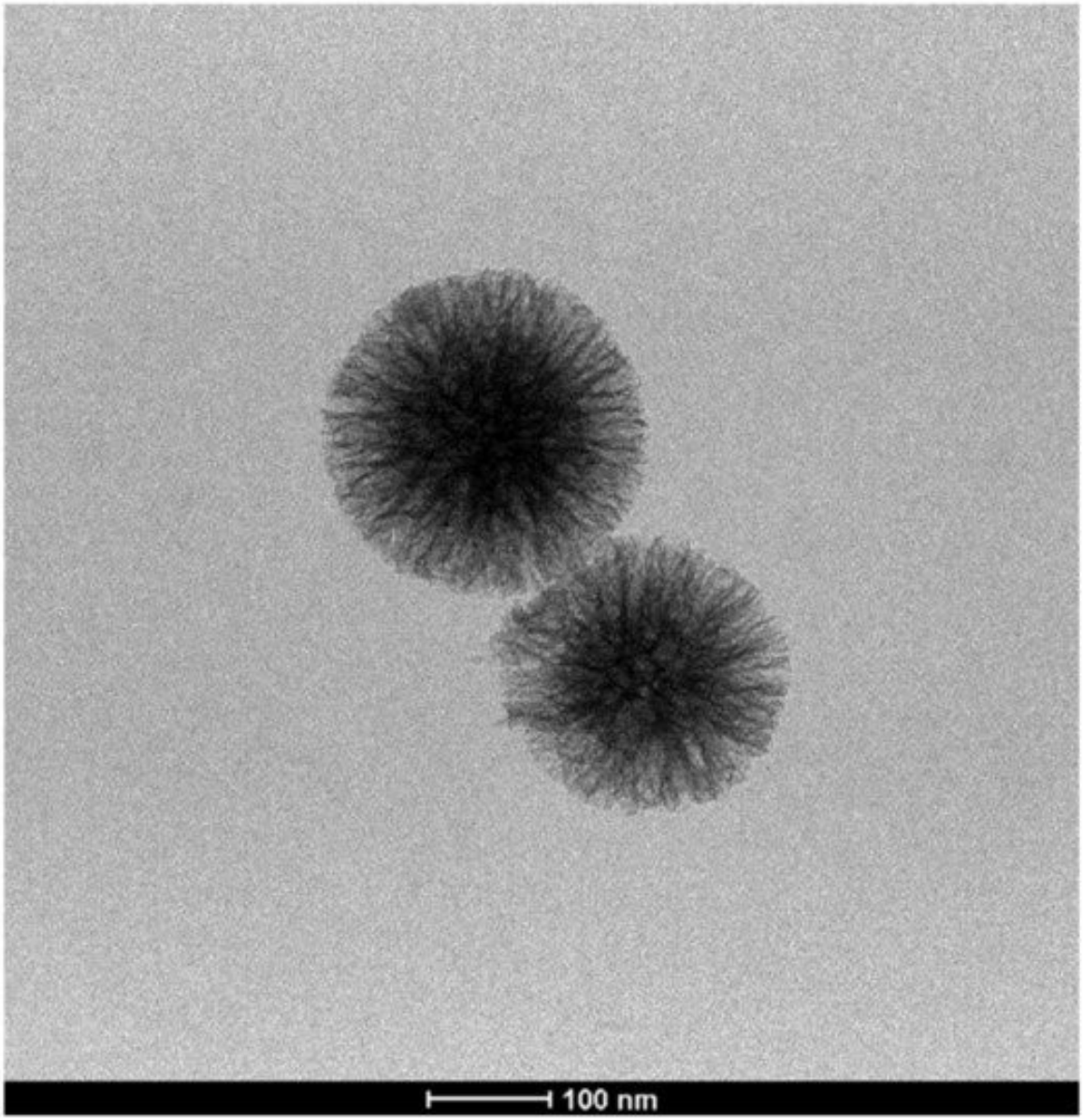

(a)
1 μm
(b)
1 μm
(c)
500 nm
(d)
2 μm

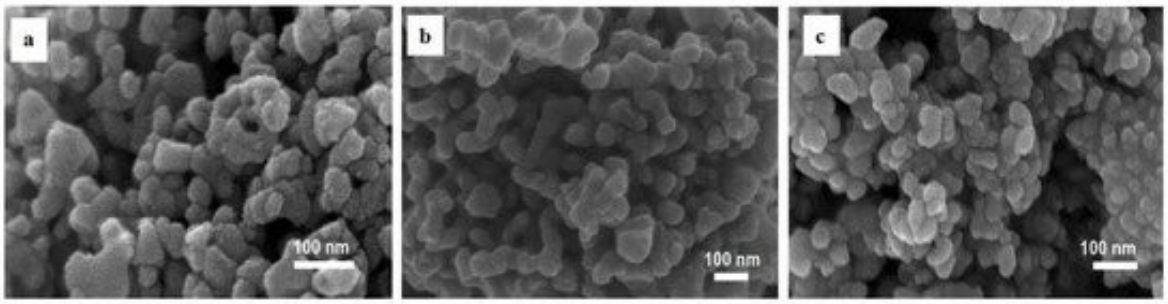

(a)
200 nm
(b)
200 nm
(c)
200 nm

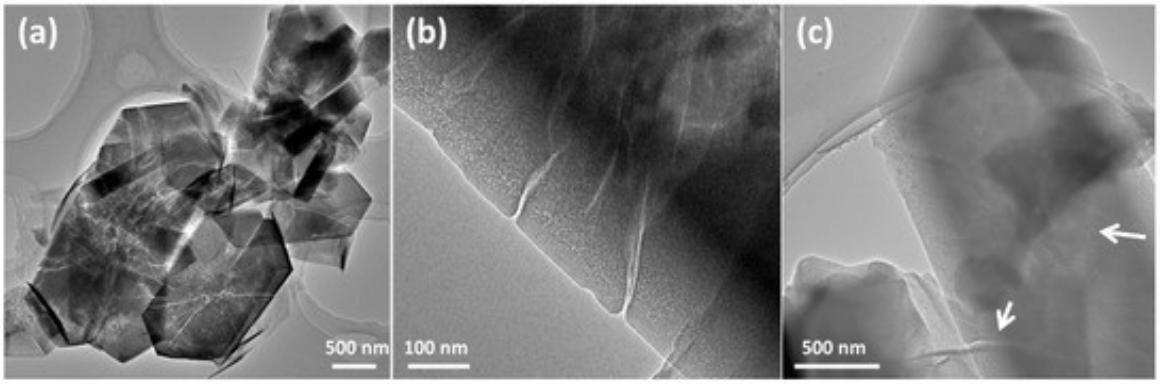

(a) HT1.5
200nm
(b) HT2
200nm
(c) HT3
200nm
(d) HT4
200nm

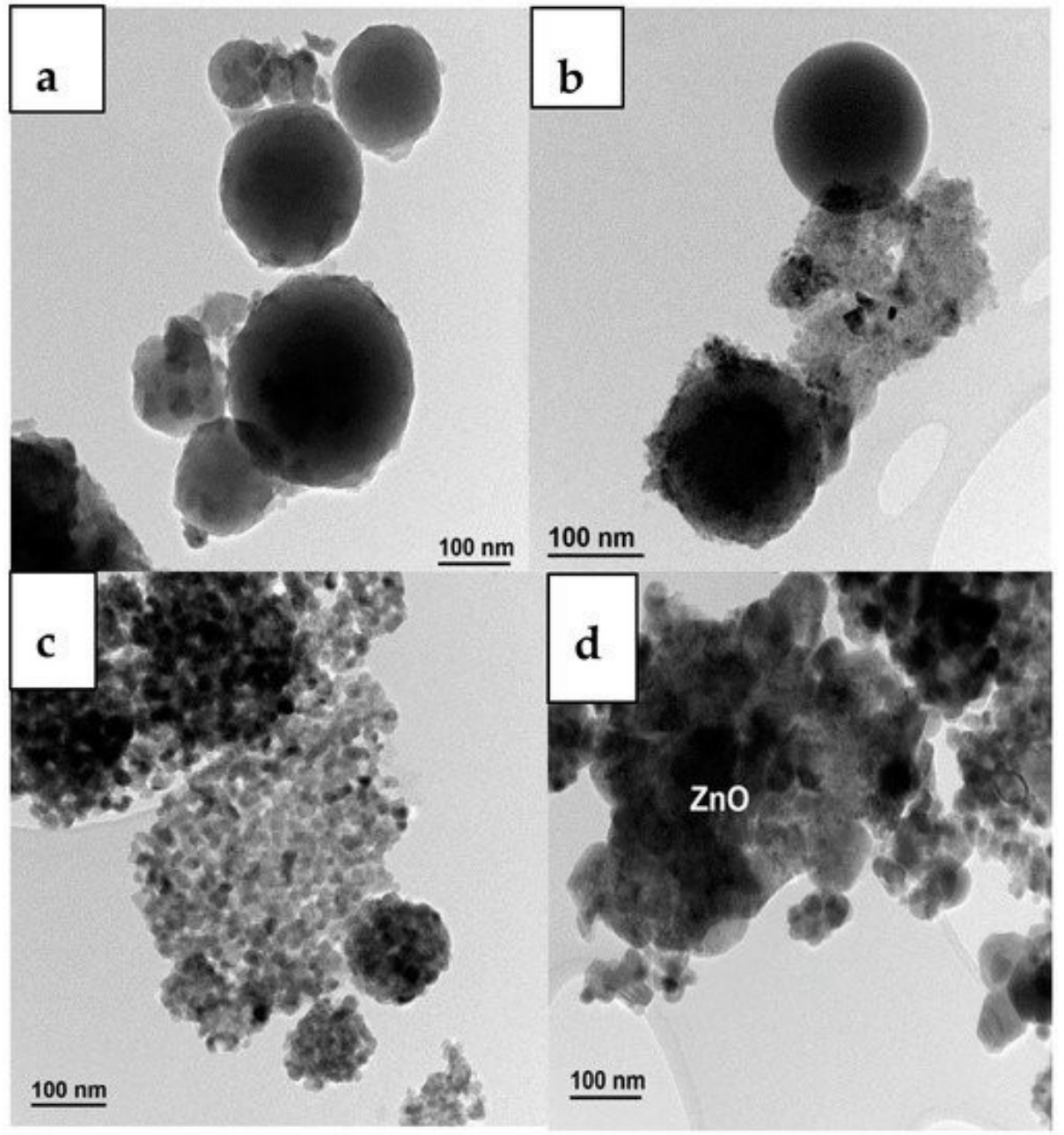

200 nm

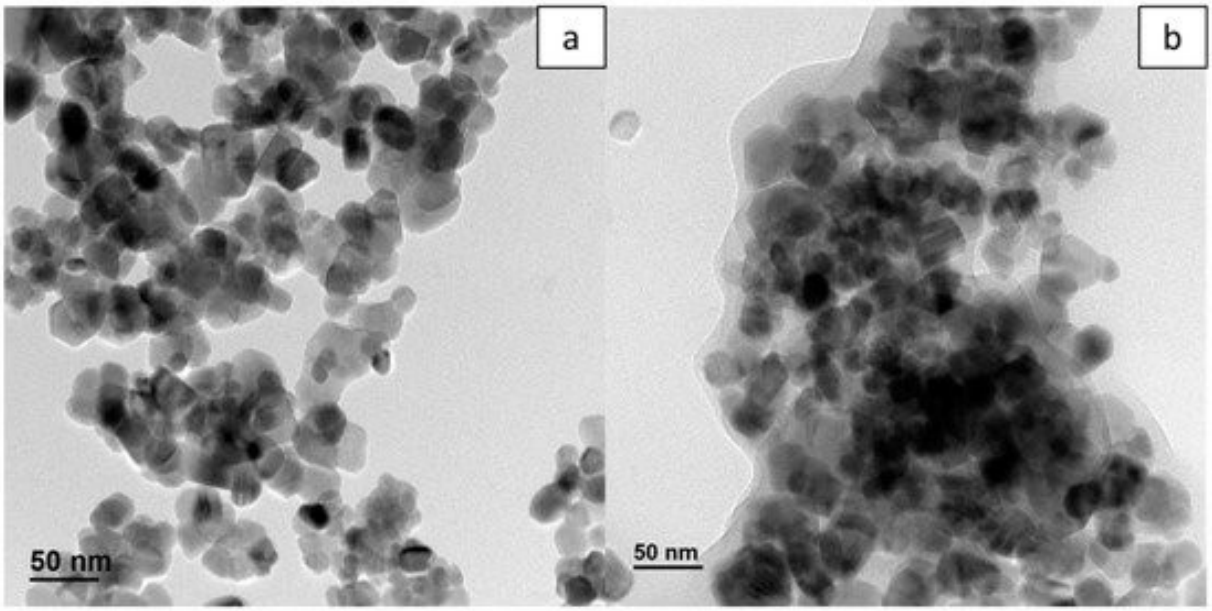

100 nm

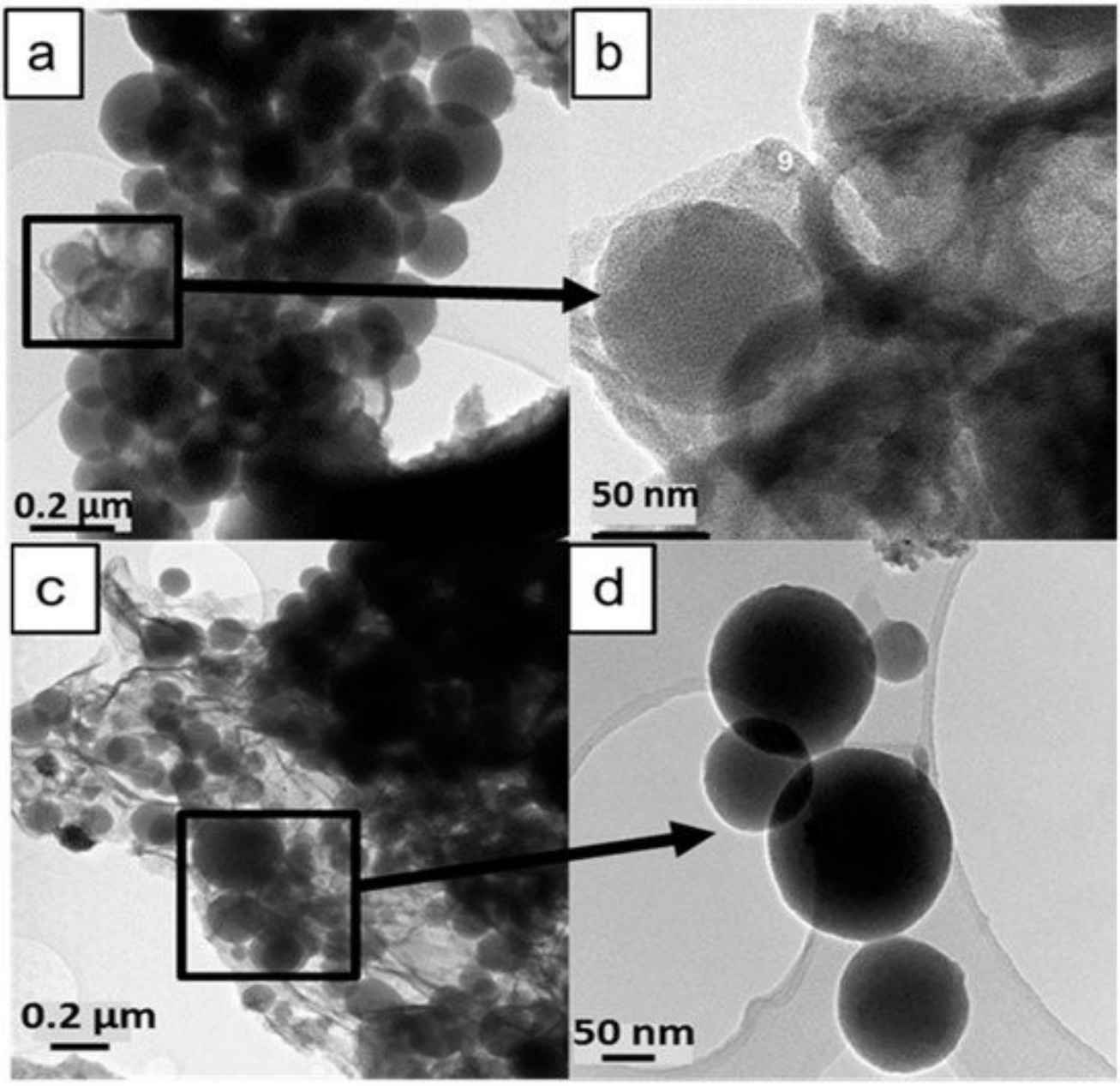

100 nm

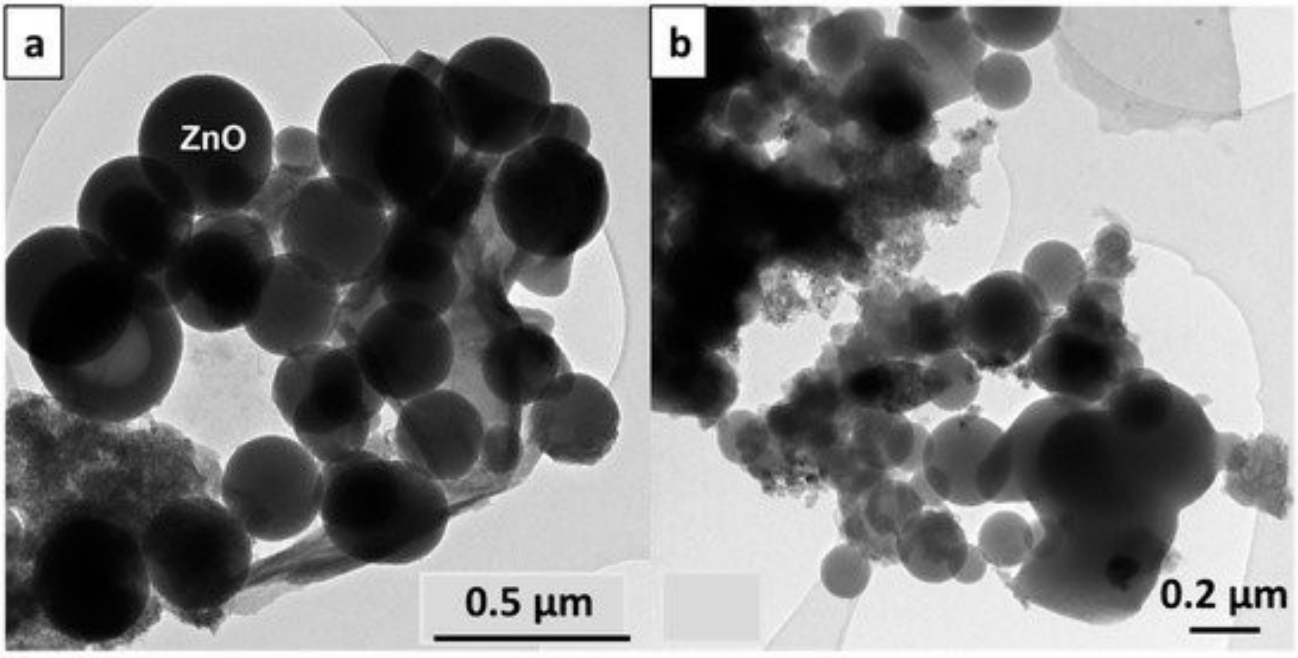

a
100 nm
b
100 nm
c
100 nm


(a)
500 nm
(b)
100 nm
(c)
500 nm

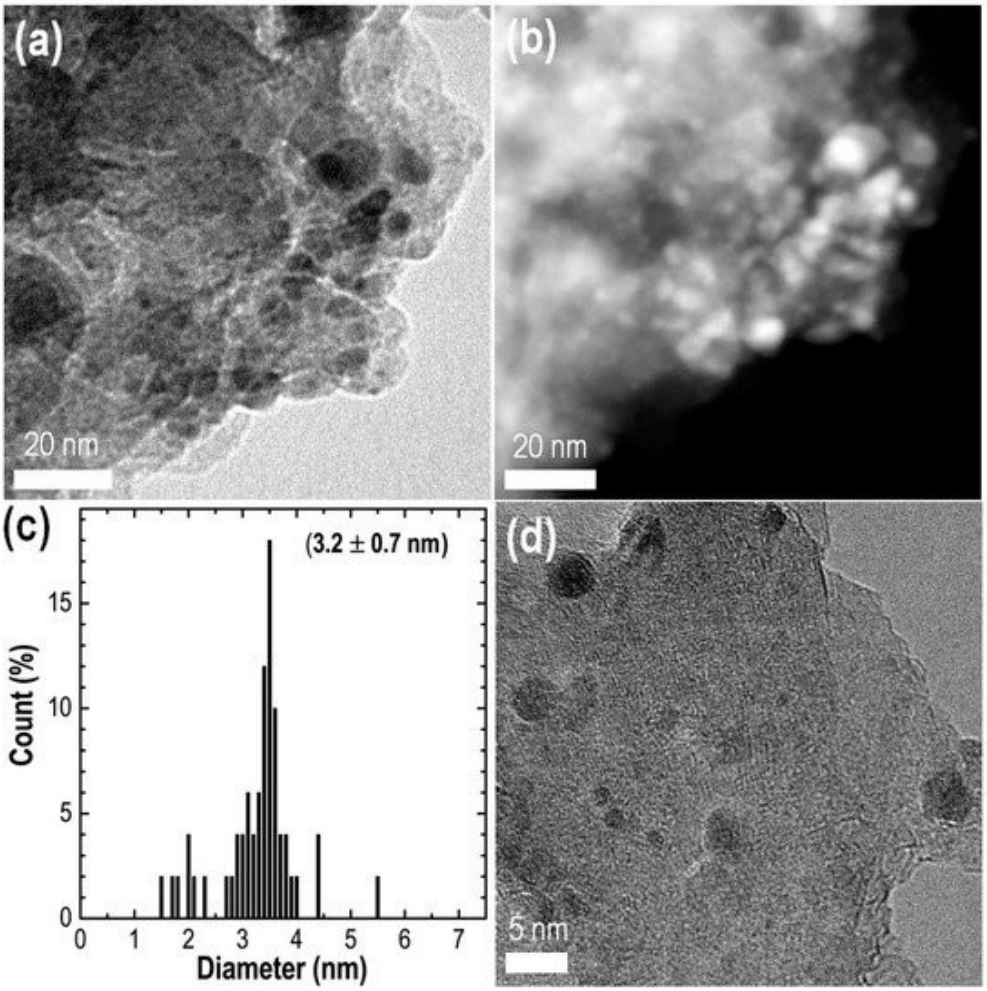

a
100 nm
b
100 nm
c
100 nm
d
ZnO
100 nm

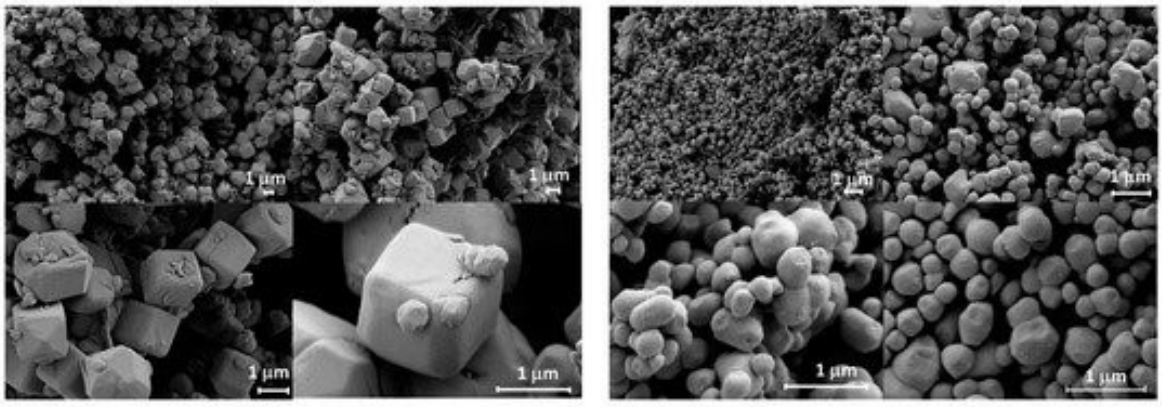

a
50 nm
b
50 nm


a
b
0.2 µm
50 nm
c
d
0.2 µm
50 nm

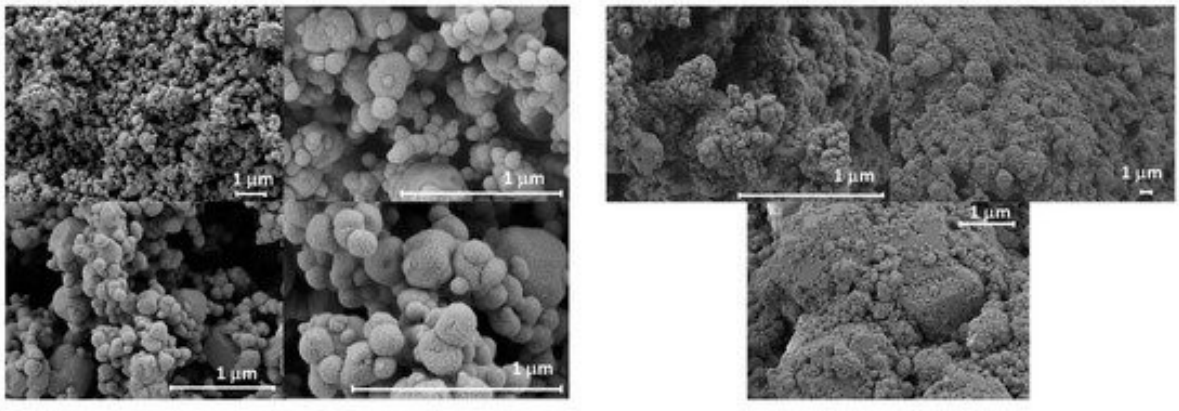

a
ZnO
0.5 µm
b
0.2 µm

[Argentum <Arg>:

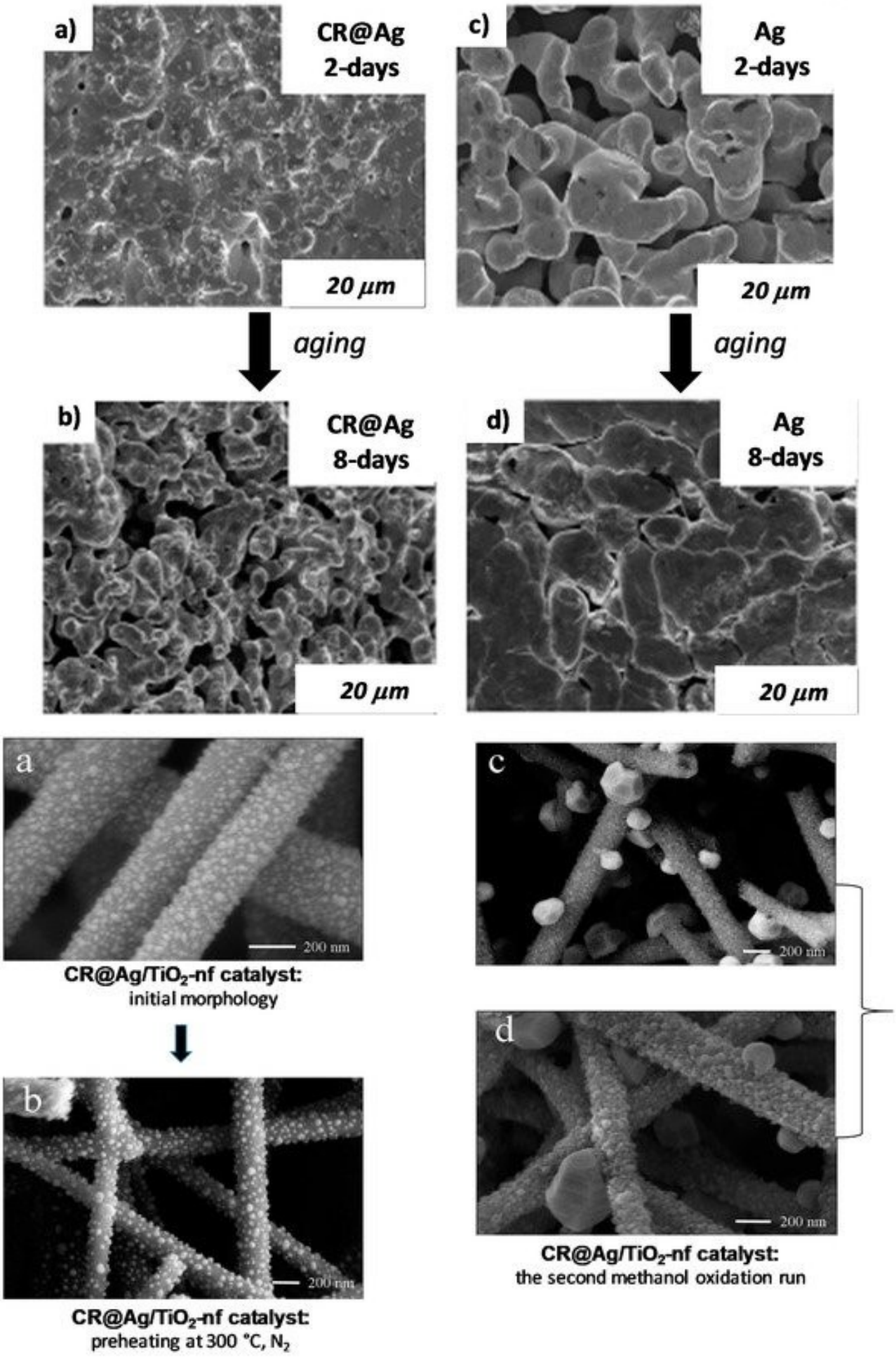




(a) (b)

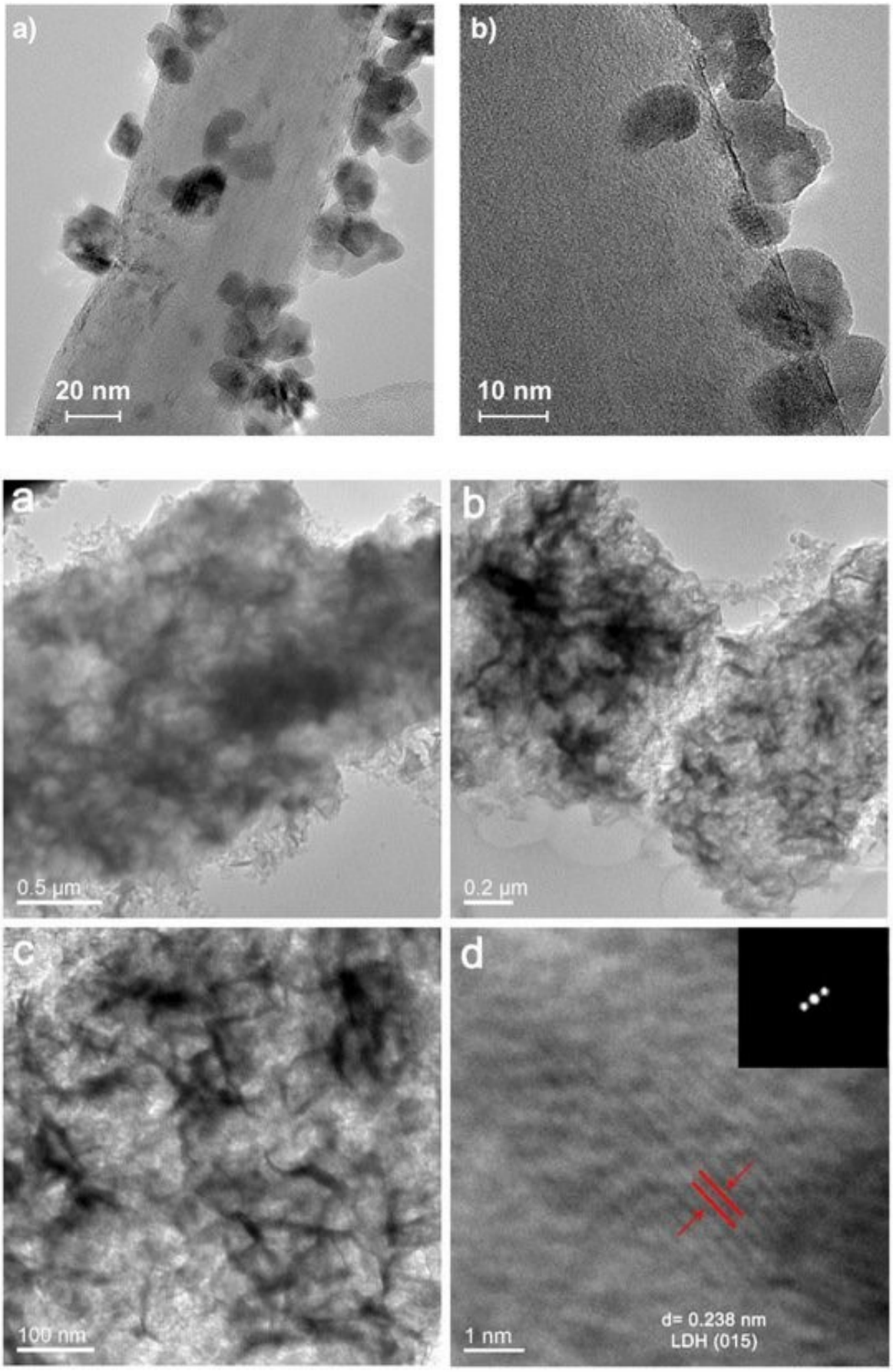


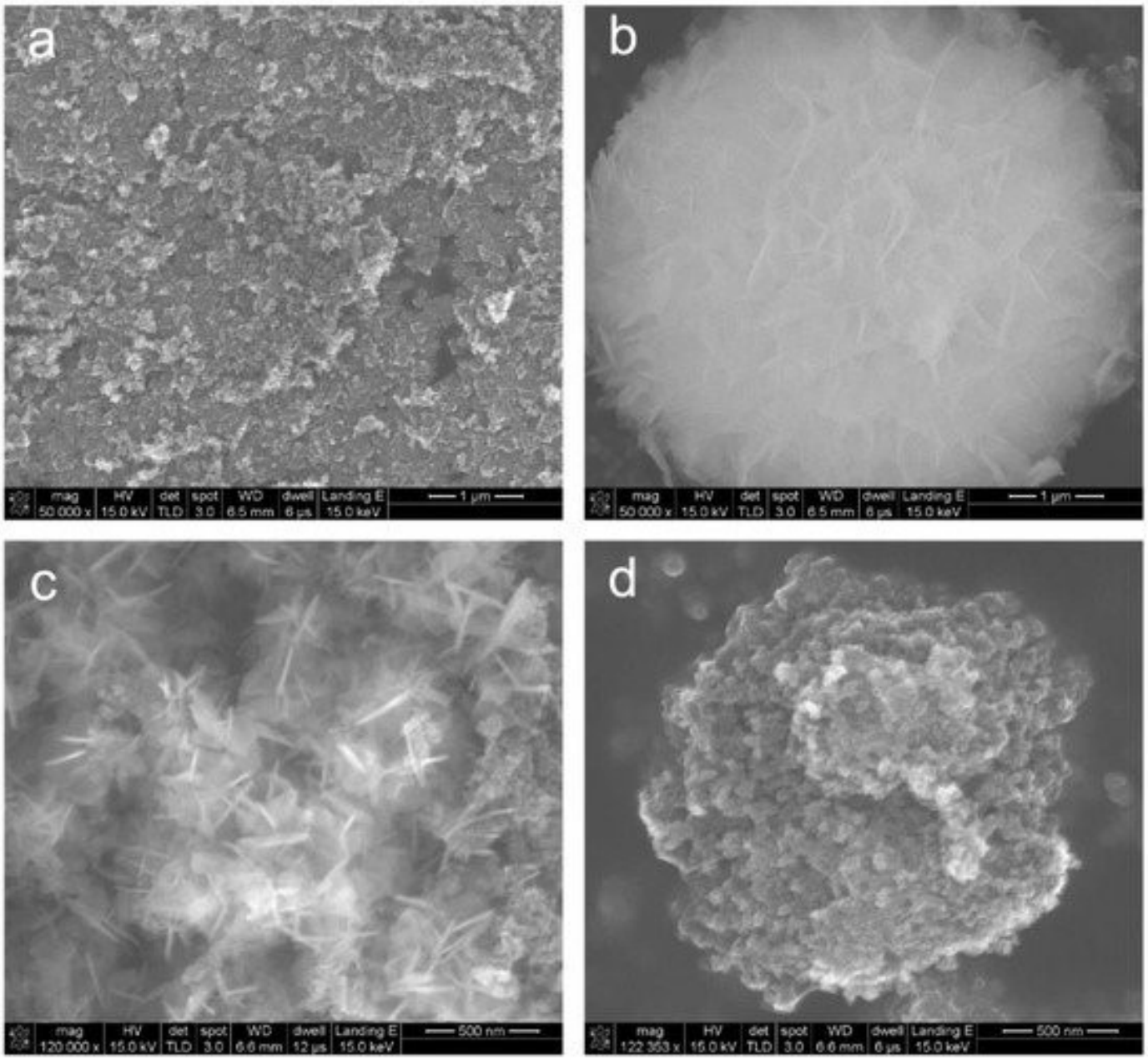
(c) (d)

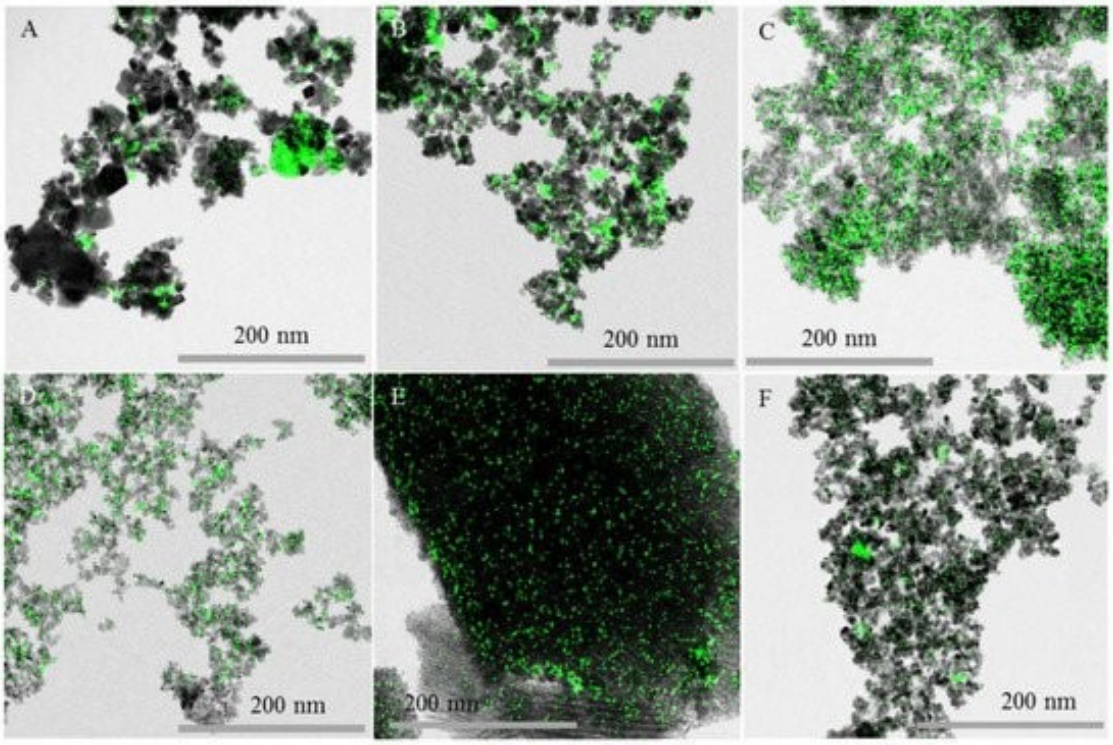

a)
CR@Ag
2-days
20 μm
aging
b)
CR@Ag
8-days
20 μm
c)
Ag
2-days
20 μm
aging
d)
Ag
8-days
20 μm
a
200 nm
CR@Ag/TiO2-nf catalyst:
initial morphology
b
200 nm
CR@Ag/TiO2-nf catalyst:
preheating at 300 °C, N2
c
200 nm
d
200 nm
CR@Ag/TiO2-nf catalyst:
the second methanol oxidation run

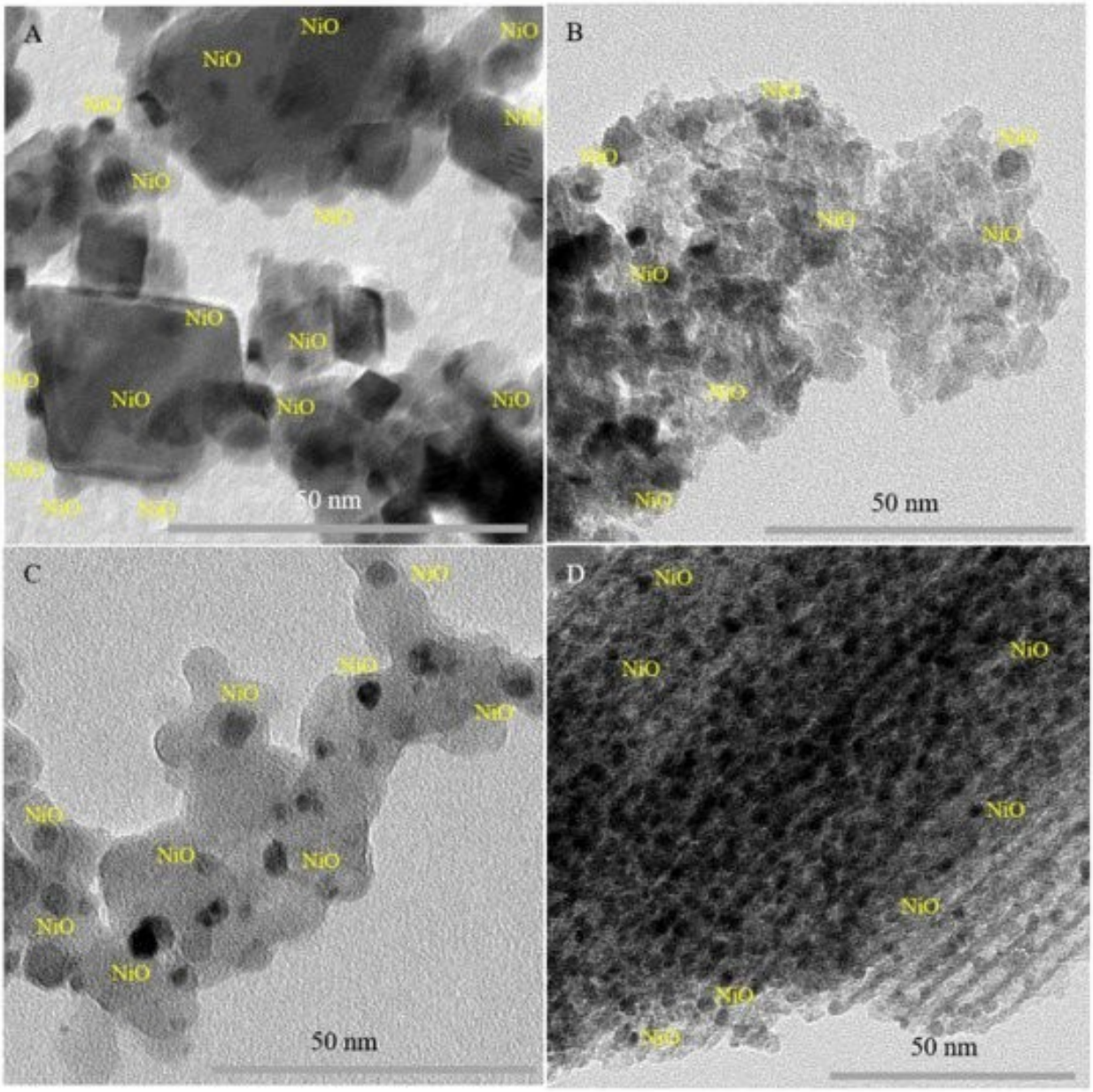
Arg]

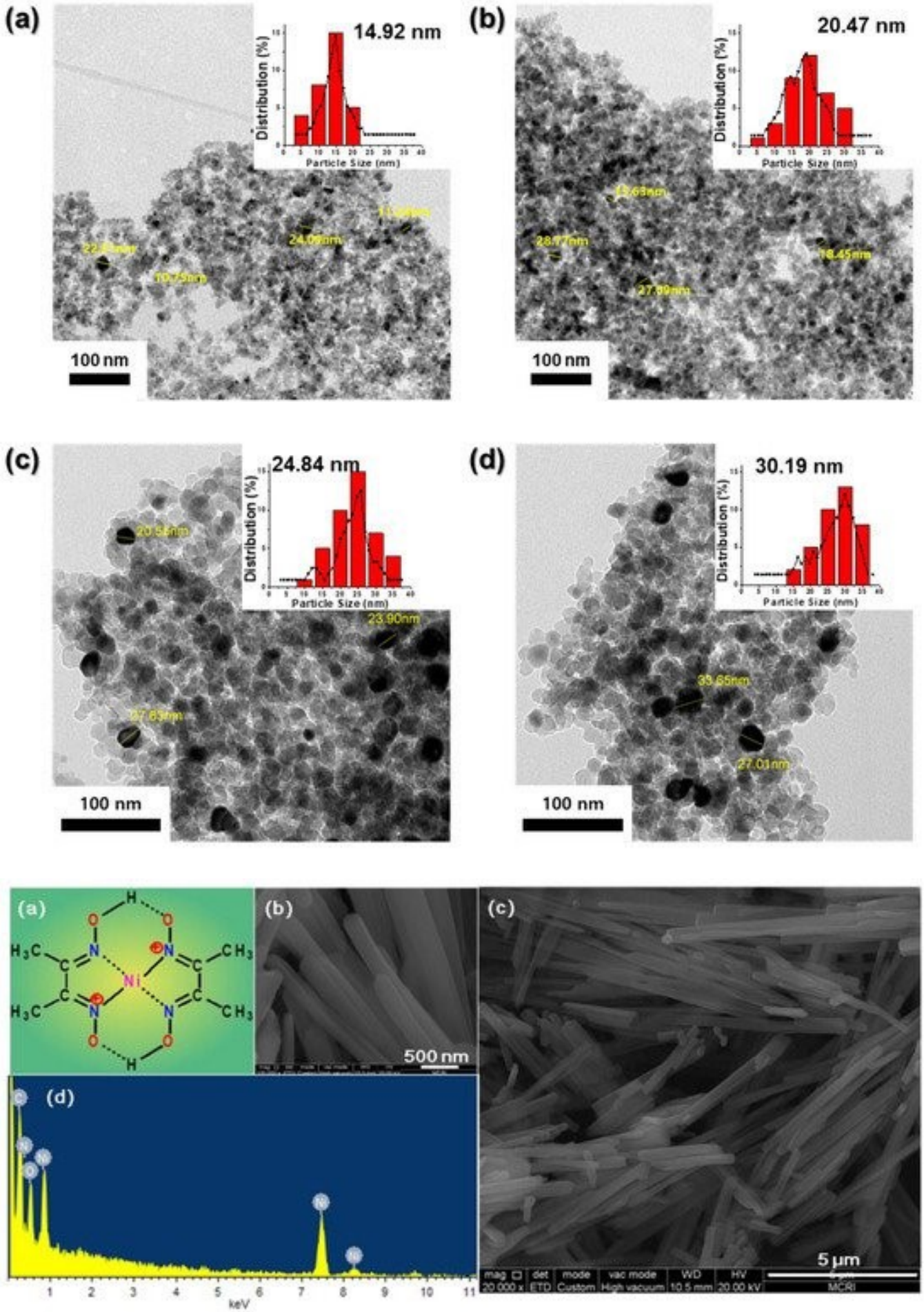
[Nickel <Ni>:

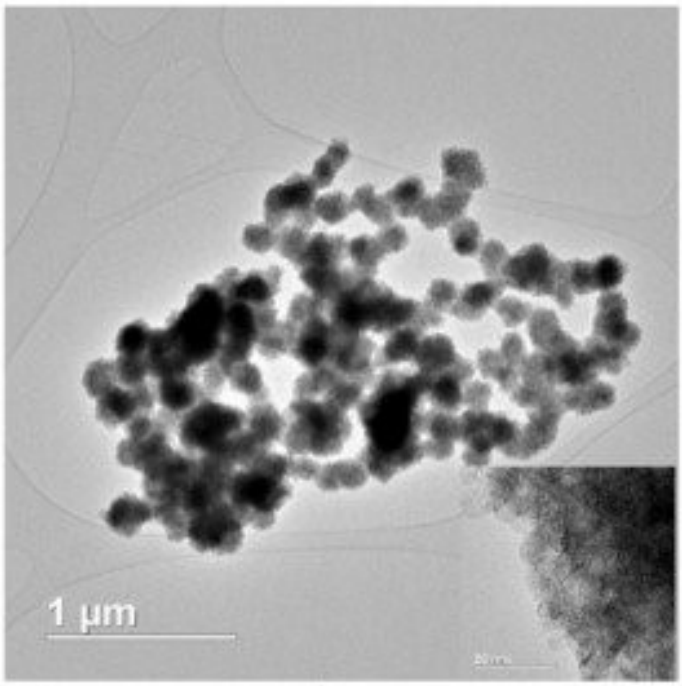



a
mag 50 000 x | HV 15.0 kV | det TLD | spot 3.0 | WD 6.5 mm | dwell 6 µs | Landing E 15.0 keV | 1 µm
b
mag 50 000 x | HV 15.0 kV | det TLD | spot 3.0 | WD 6.5 mm | dwell 6 µs | Landing E 15.0 keV | 1 µm
c
mag 120 000 x | HV 15.0 kV | det TLD | spot 3.0 | WD 6.6 mm | dwell 12 µs | Landing E 15.0 keV | 500 nm
d
mag 122 353 x | HV 15.0 kV | det TLD | spot 3.0 | WD 6.6 mm | dwell 6 µs | Landing E 15.0 keV | 500 nm

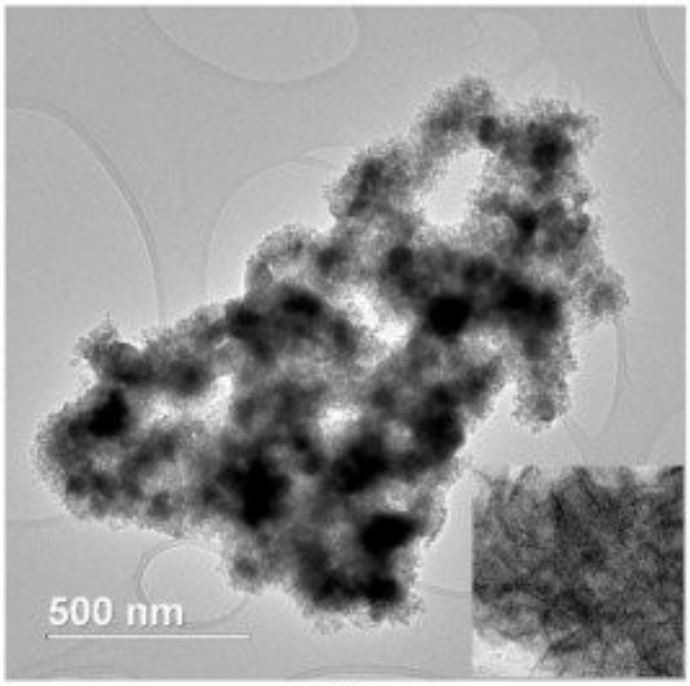

A
200 nm
B
200 nm
C
200 nm
D
200 nm
E
200 nm
F
200 nm


A
NiO
50 nm
B
NiO
50 nm
C
NiO
50 nm
D
NiO
50 nm

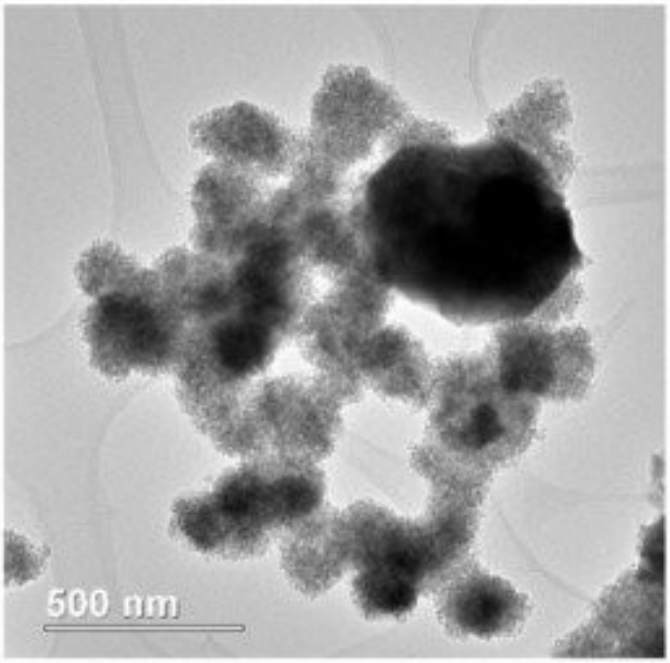

(a)
14.92 nm
Distribution (%)
Particle Size (nm)
24.09nm
100 nm
(b)
20.47 nm
Distribution (%)
Particle Size (nm)
28.77nm
18.45nm
27.89nm
100 nm
(c)
24.84 nm
Distribution (%)
Particle Size (nm)
20.56nm
23.90nm
27.63nm
100 nm
(d)
30.19 nm
Distribution (%)
Particle Size (nm)
33.65nm
27.01nm
100 nm
(a)
(b)
500 nm
(c)
5 µm
(d)
keV



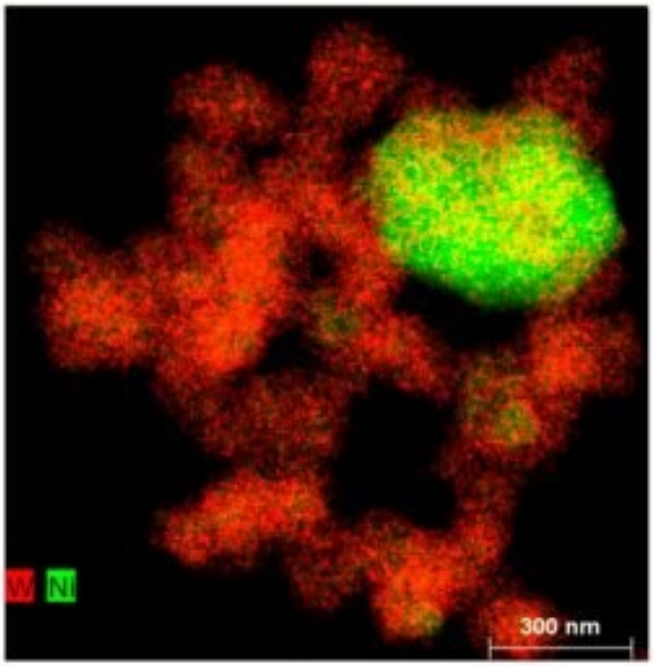
(a)



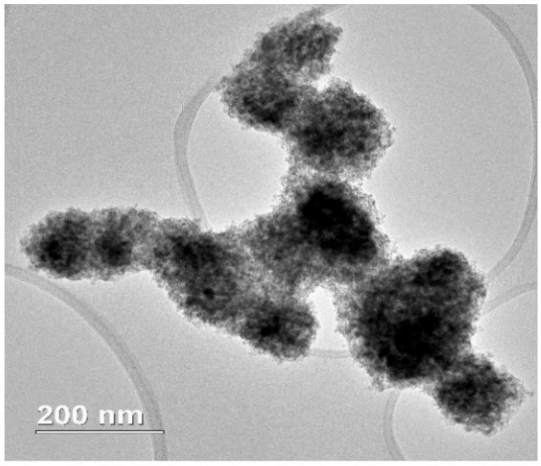
(b)



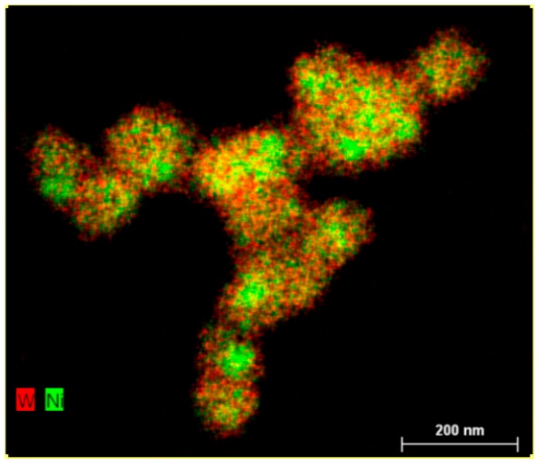
(a)



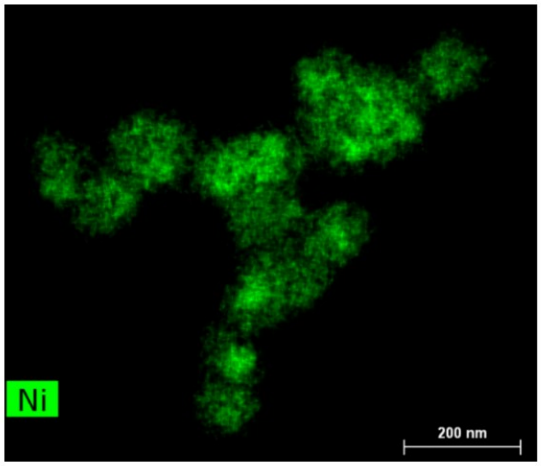
(b)


200 nm

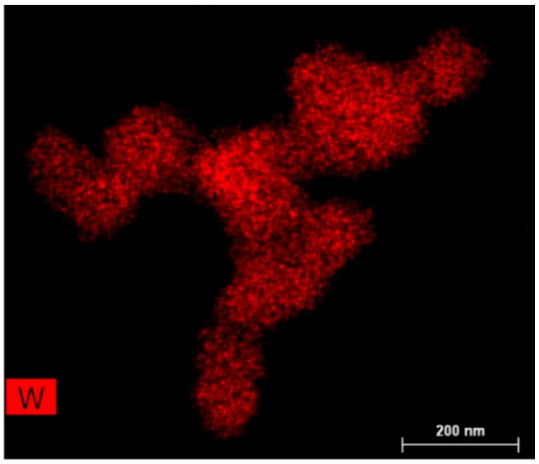
(a)


W
Ni
200 nm

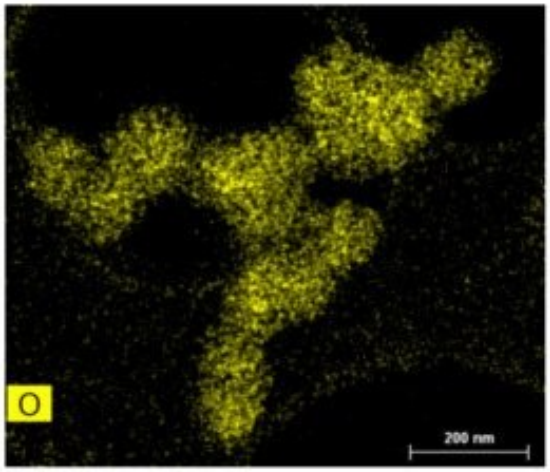
(b)


Ni
200 nm

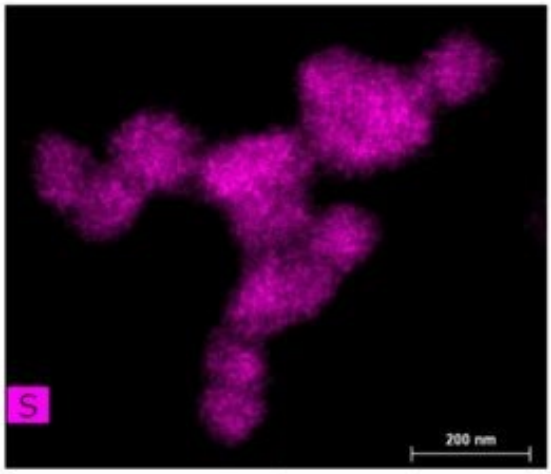
(c)


W
200 nm

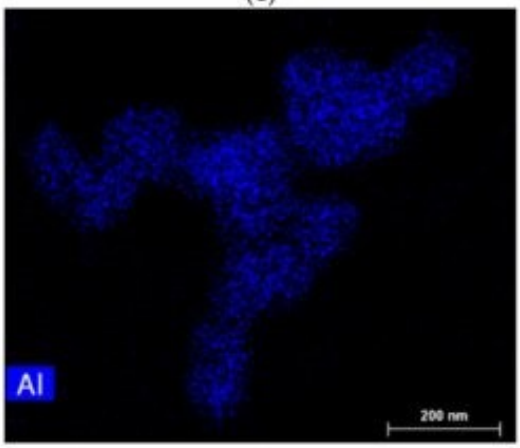
(d)


O
200 nm

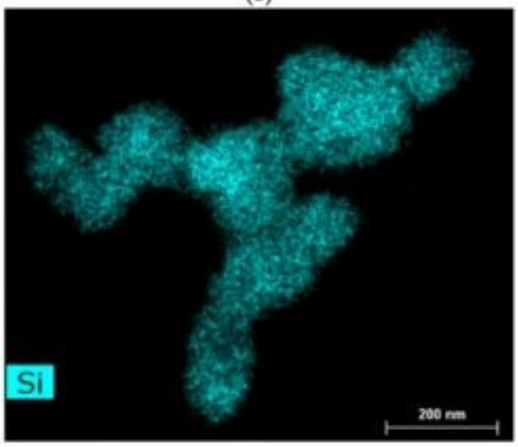
(e)


S
200 nm

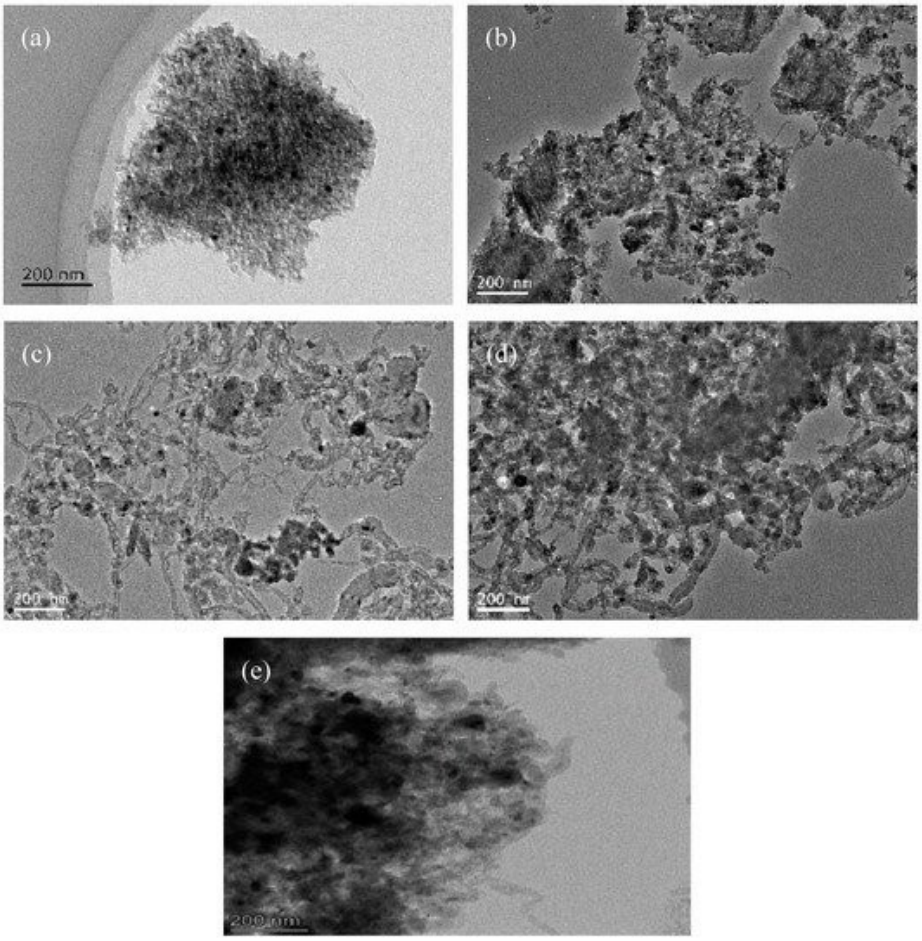
(f)

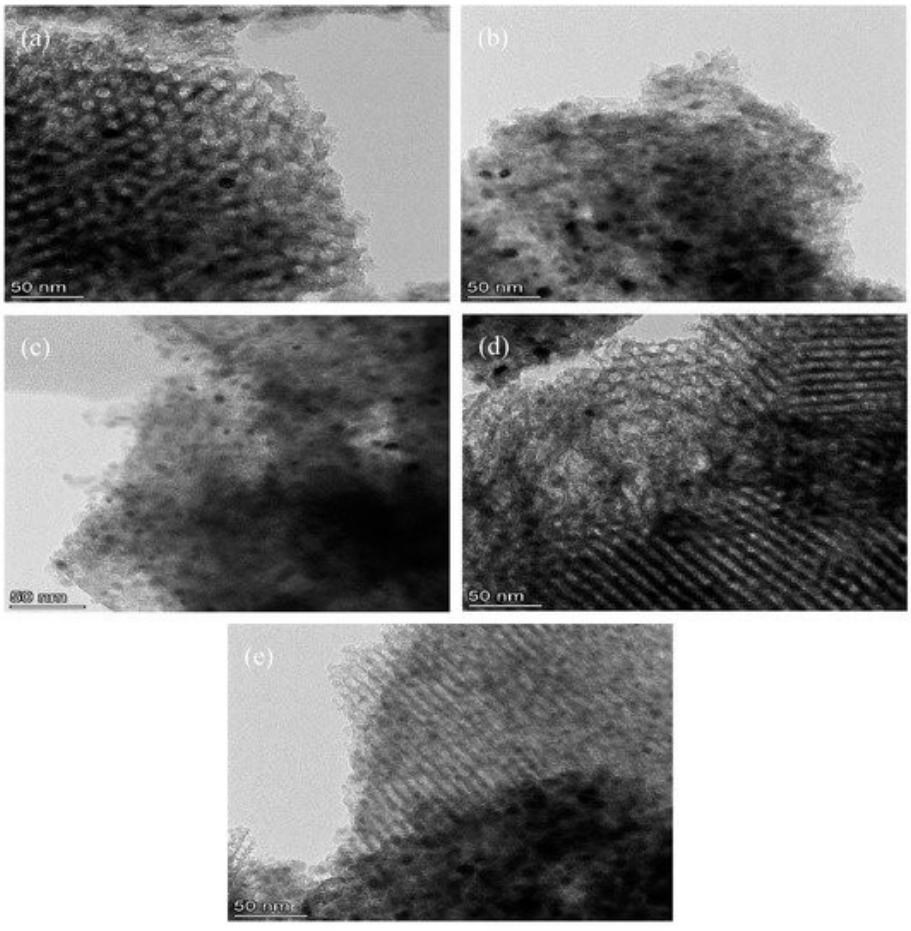

Al
200 nm

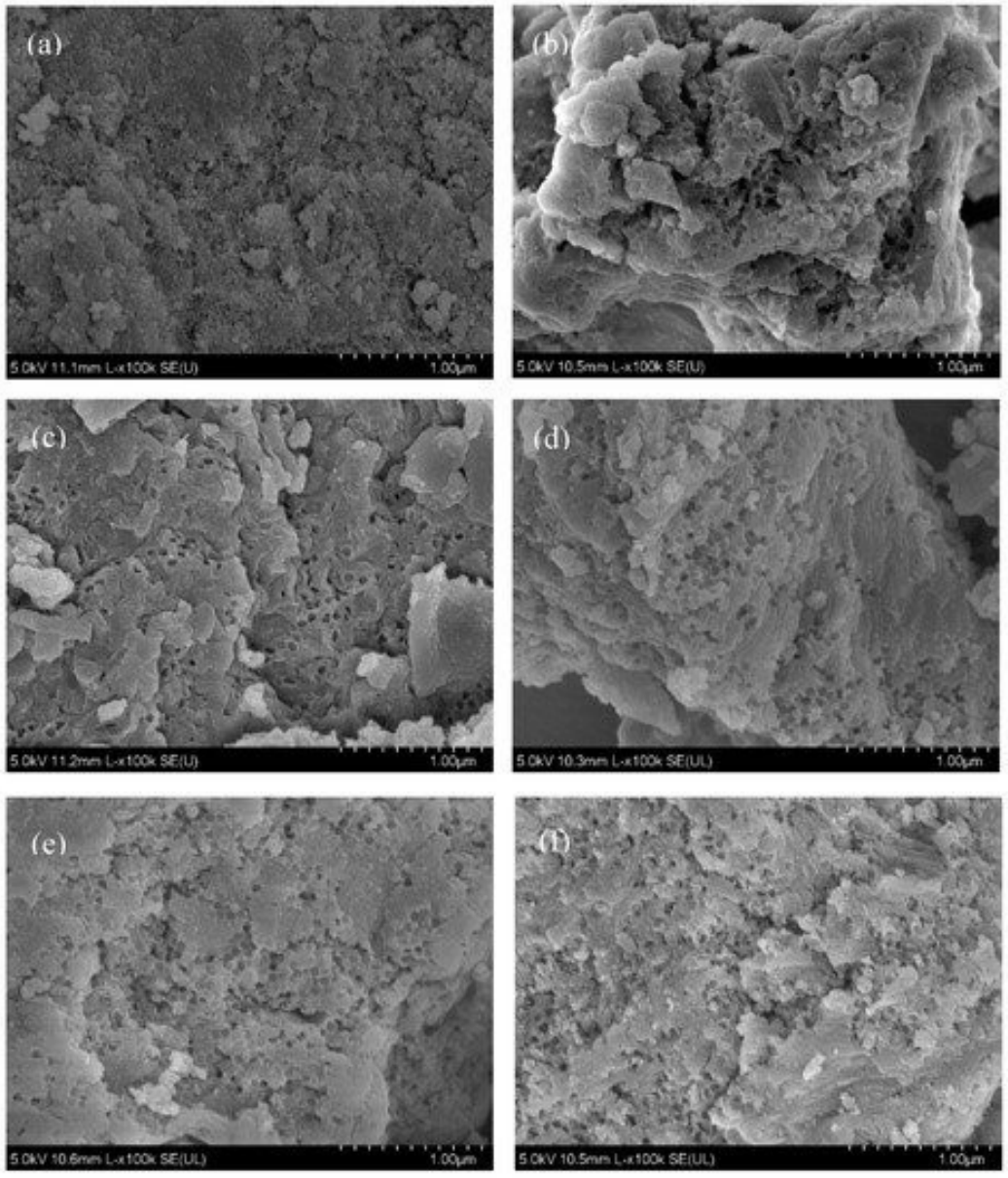
(g)

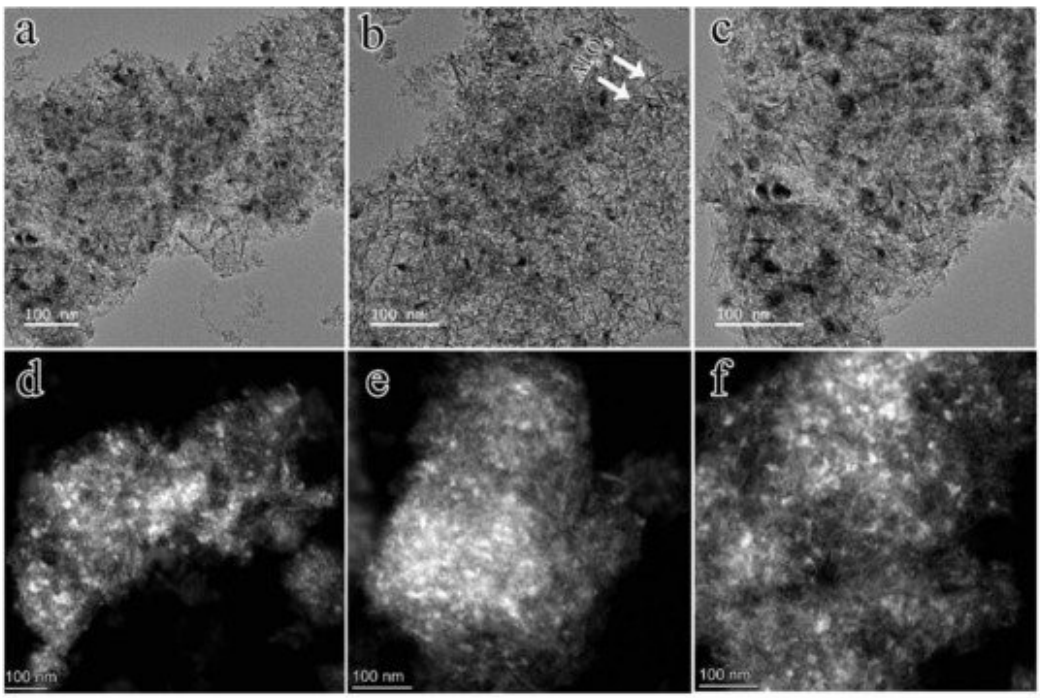

Si
200 nm

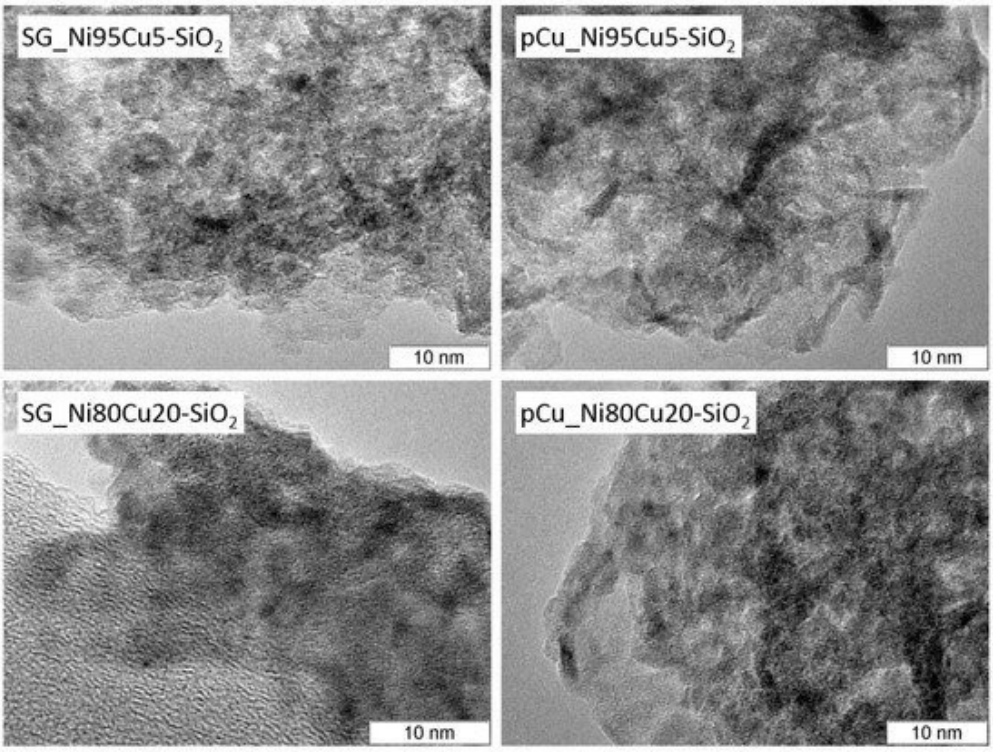
(h)

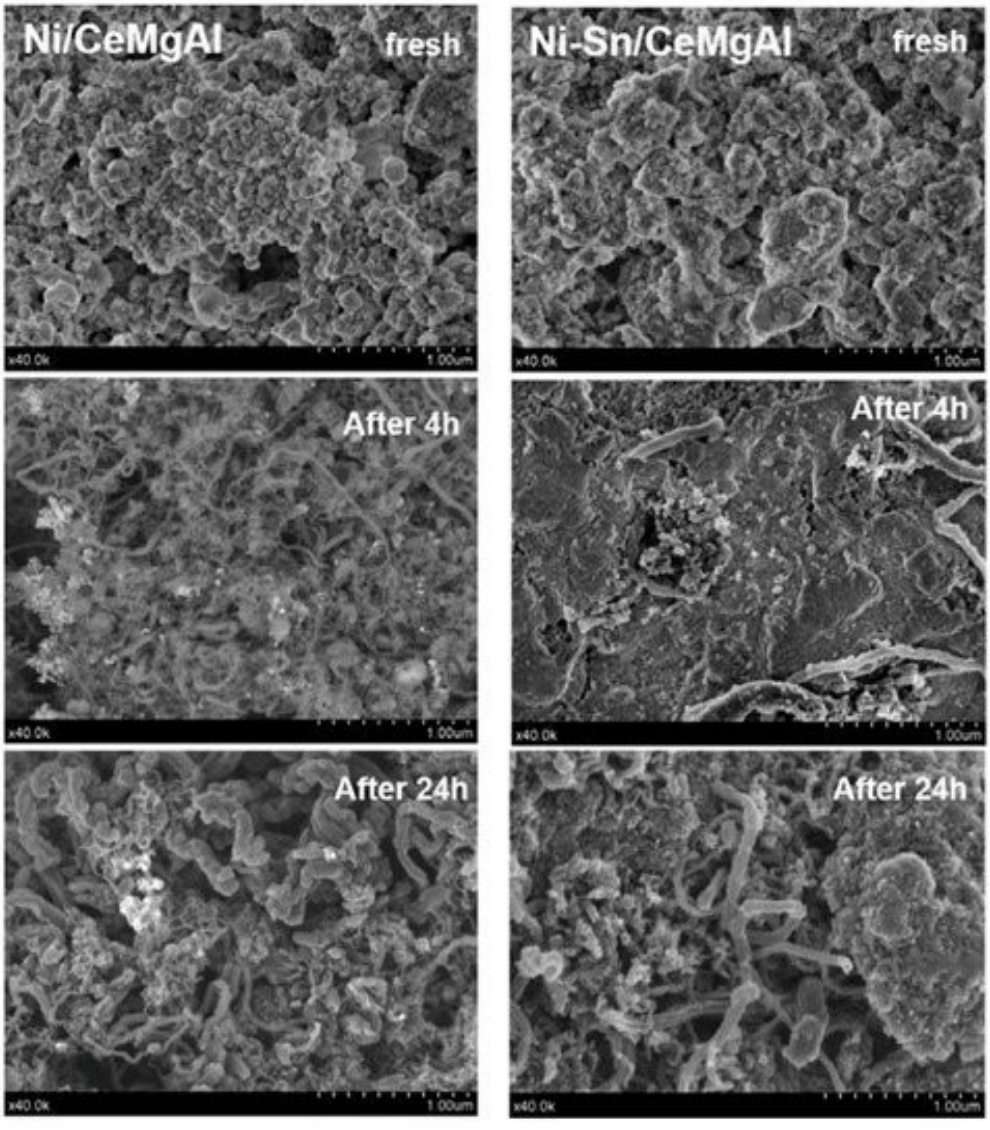

(a)
200 nm
(b)
200 nm
(c)
200 nm
(d)
200 nm
(e)
200 nm

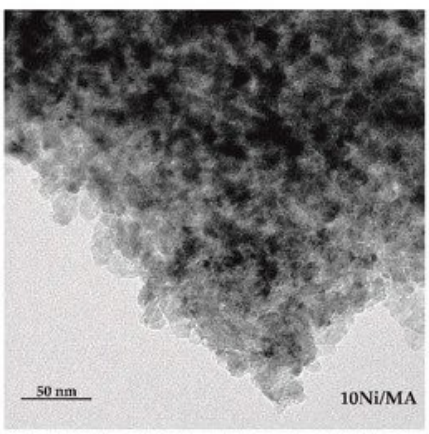

(a)
50 nm
(b)
50 nm
(c)
(d)
50 nm
(e)
50 nm

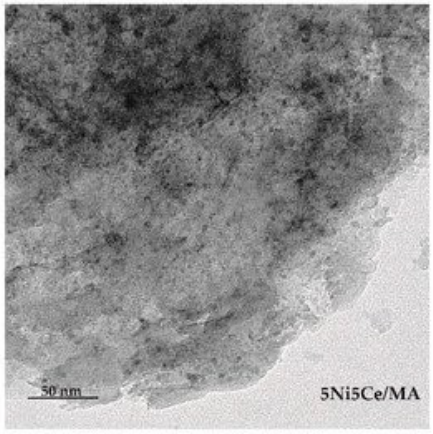

(a)
5.0kV 11.1mm L-x100k SE(U)
1.00μm
(b)
5.0kV 10.5mm L-x100k SE(U)
1.00μm
(c)
5.0kV 11.2mm L-x100k SE(U)
1.00μm
(d)
5.0kV 10.3mm L-x100k SE(UL)
1.00μm
(e)
5.0kV 10.6mm L-x100k SE(UL)
1.00μm
(f)
5.0kV 10.5mm L-x100k SE(UL)
1.00μm

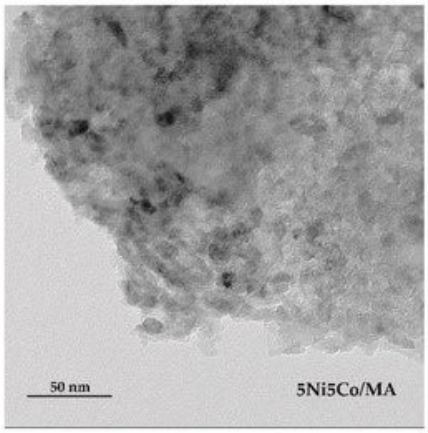

a
100 nm
b
0.2 nm
100 nm
c
100 nm
d
100 nm
e
100 nm
f
100 nm


SG_Ni95Cu5-SiO2
10 nm
pCu_Ni95Cu5-SiO2
10 nm
SG_Ni80Cu20-SiO2
10 nm
pCu_Ni80Cu20-SiO2
10 nm


Ni/CeMgAl
fresh
Ni-Sn/CeMgAl
fresh
After 4h
After 4h
After 24h
After 24h







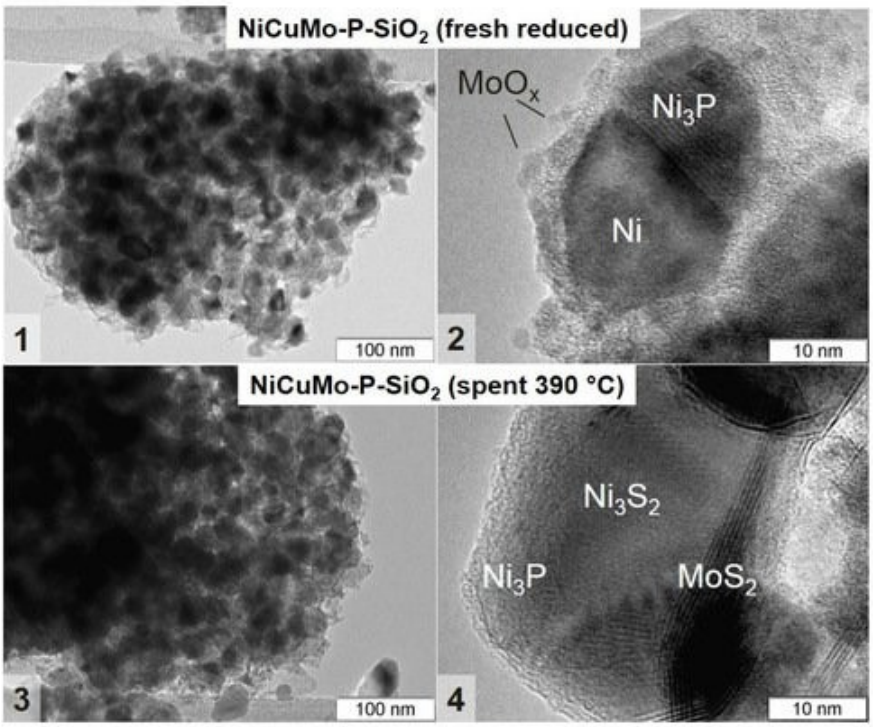
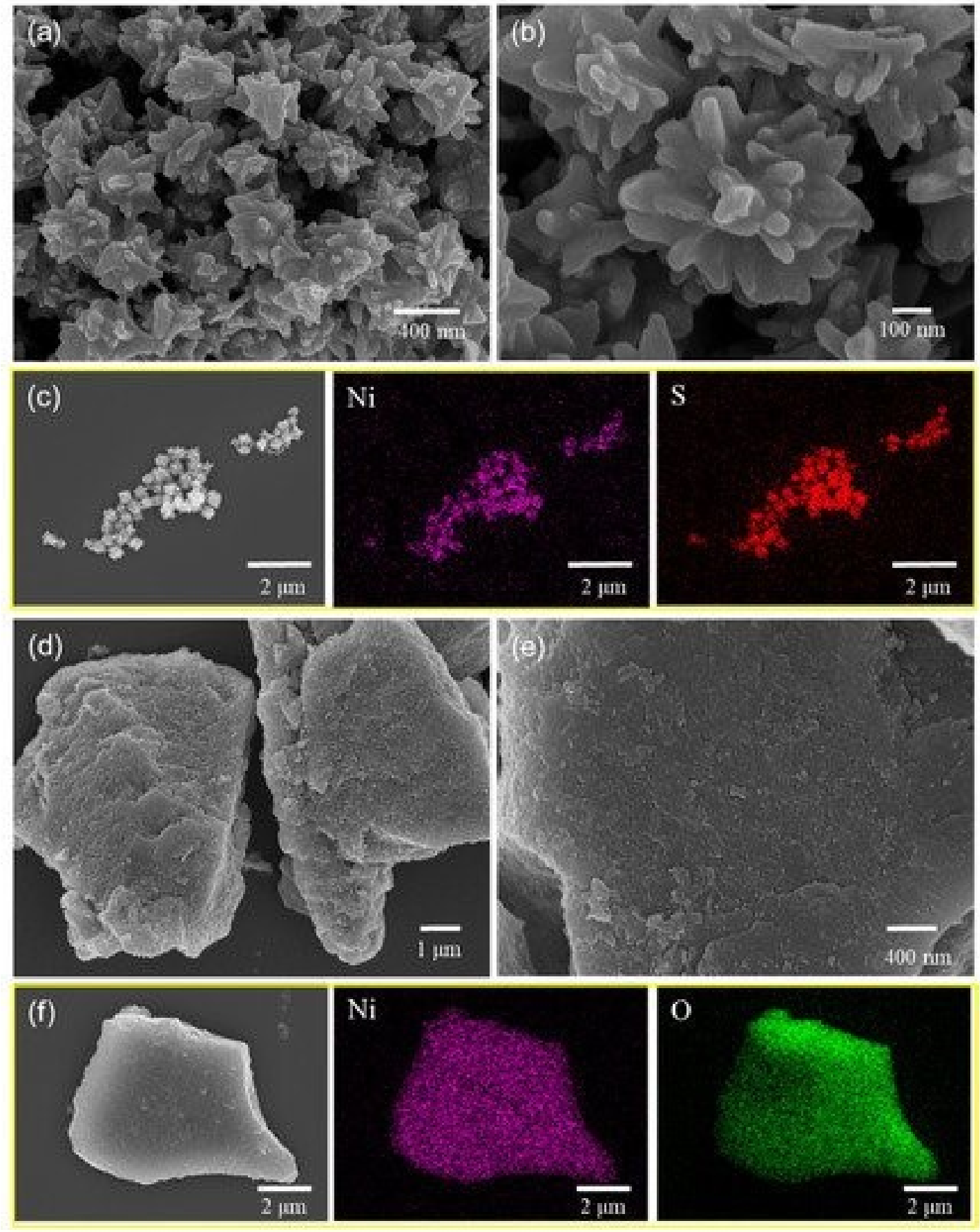
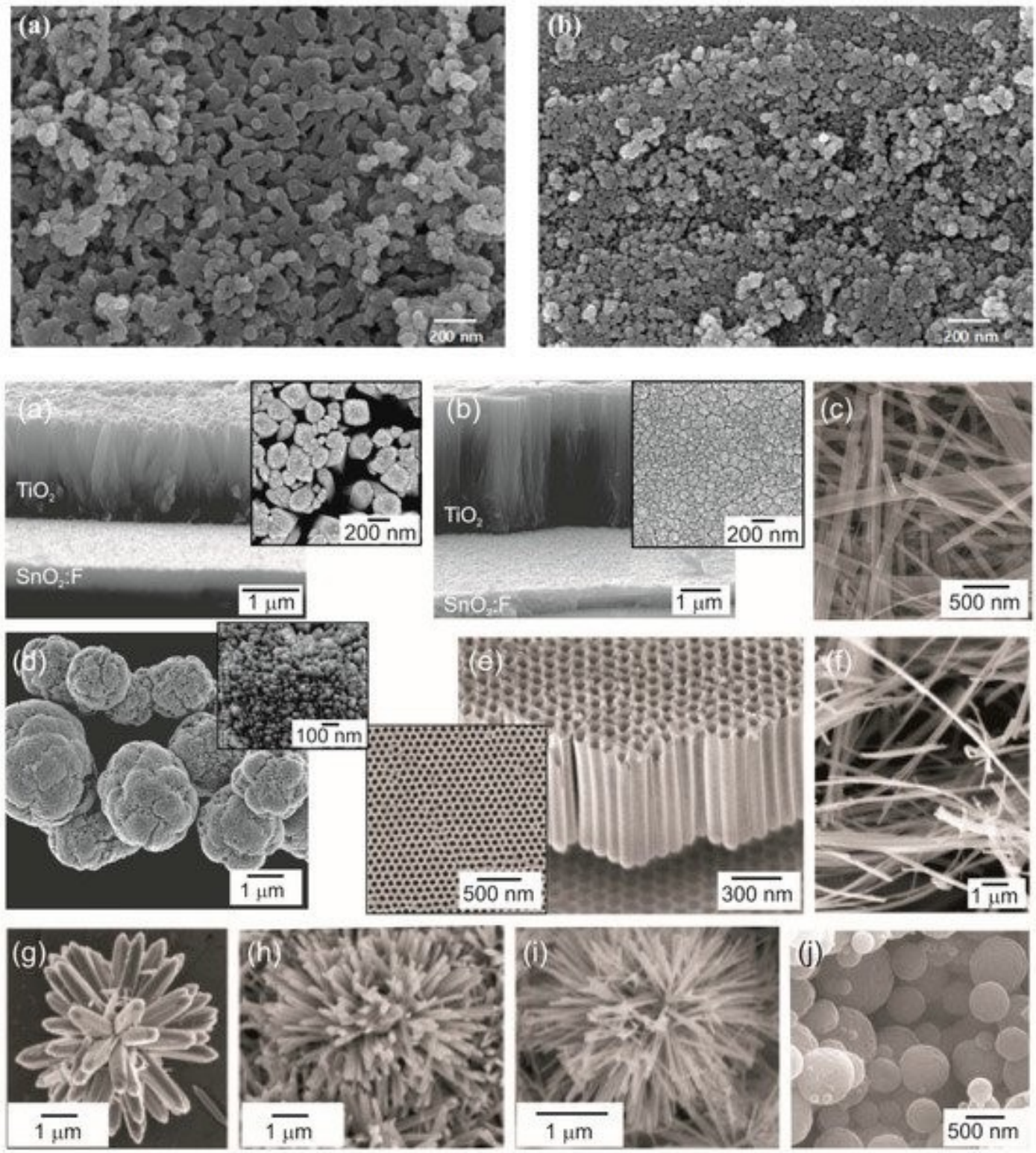


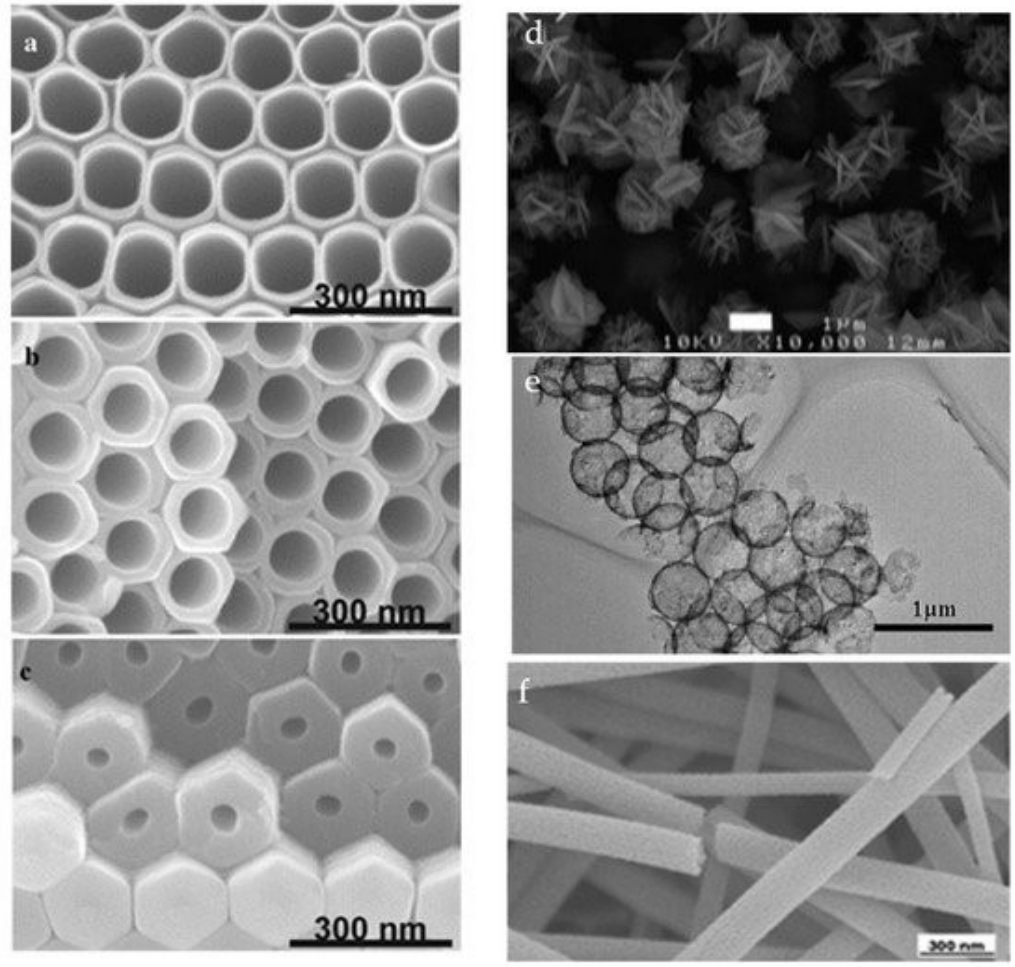
Image №	Atomic % (EDX analysis)					
	SiK	PK	SK	FeK	NiK	MoK
1	35.4	8.1	-	-	51.1	5.4
2	35.3	8.1	-	-	51.3	5.3
3	27.9	5.5	26.3	2.7	31.8	5.8
4	13.3	6.2	44.9	2.0	27.8	5.8

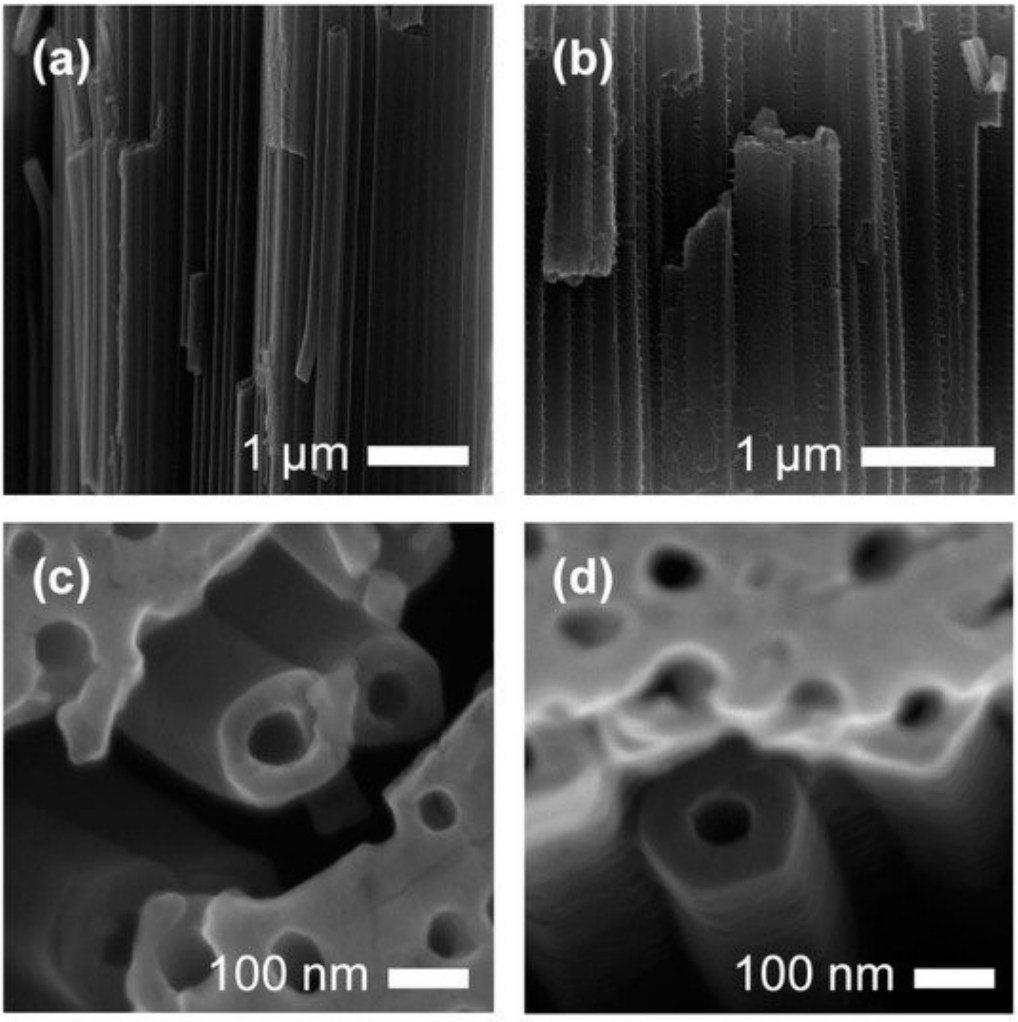


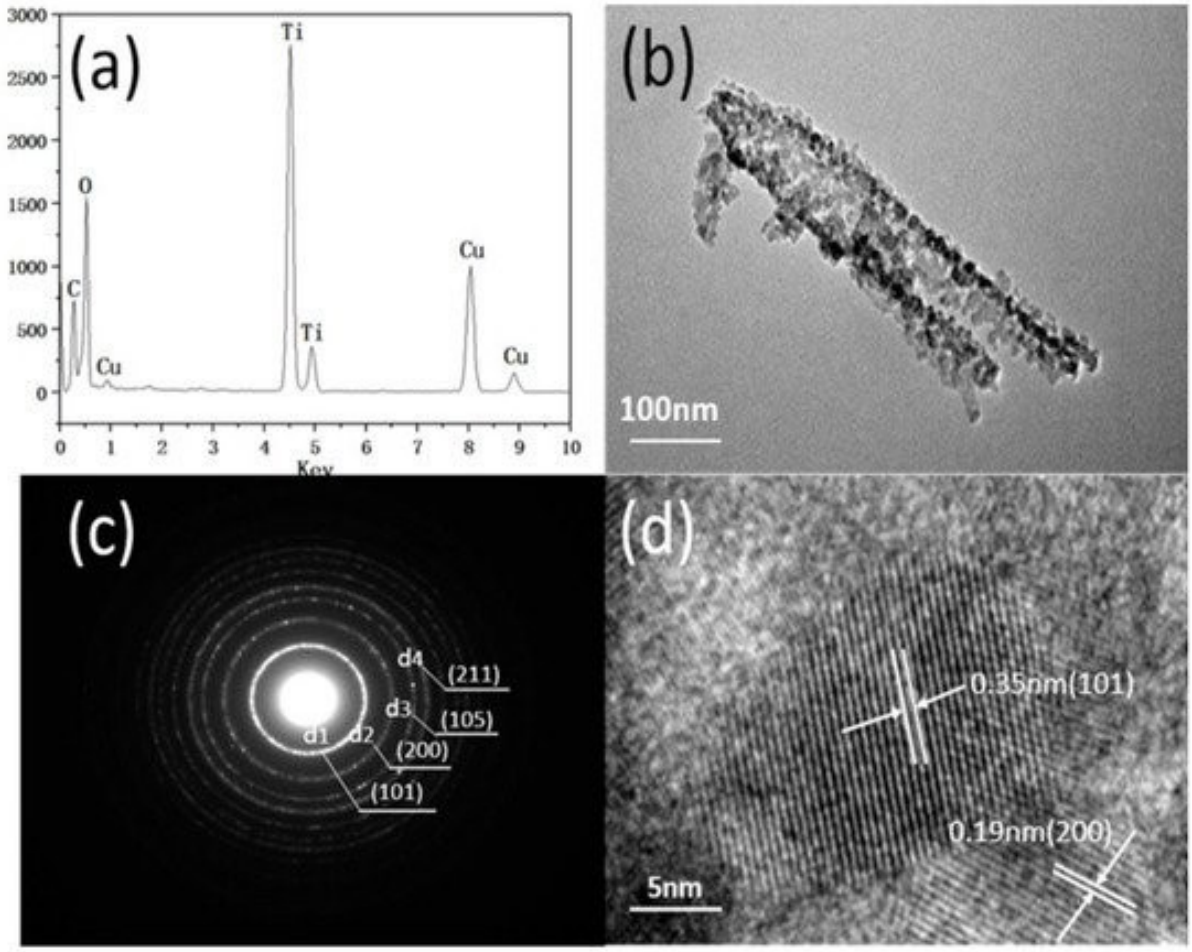
Ni]

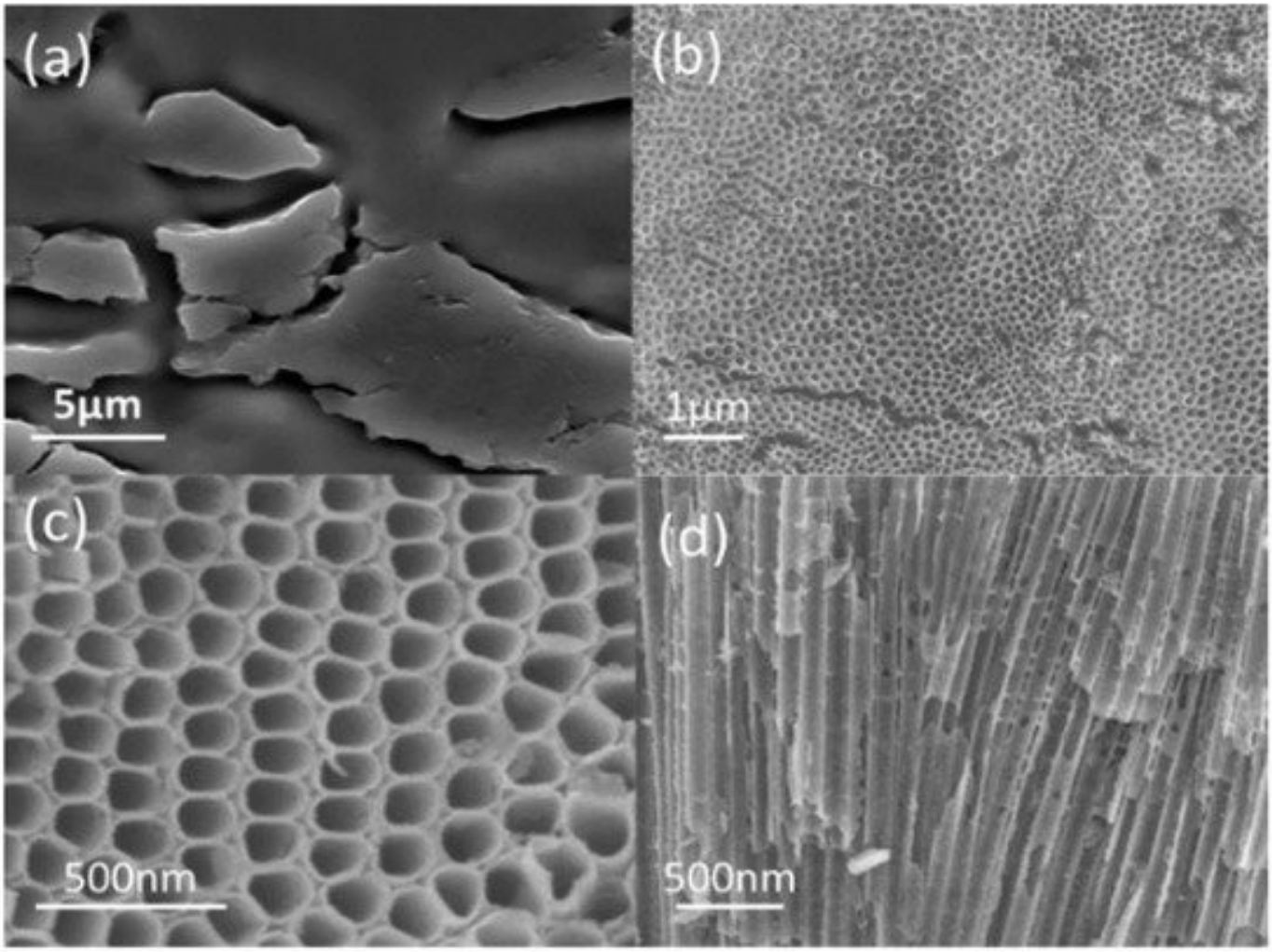
[Titanium <Ti>:

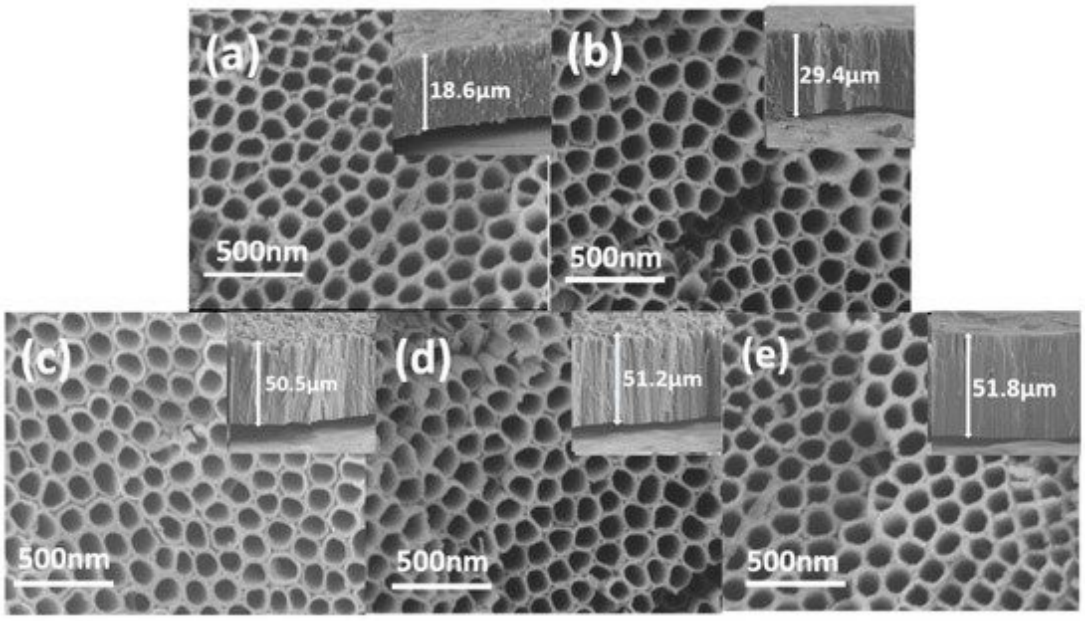

(a)
200 nm
(b)
200 nm
(a)
TiO2
SnO2:F
200 nm
1 μm
(b)
TiO2
SnO2:F
200 nm
1 μm
(c)
500 nm
(d)
100 nm
1 μm
(e)
500 nm
300 nm
(f)
1 μm
(g)
1 μm
(h)
1 μm
(i)
1 μm
(j)
500 nm

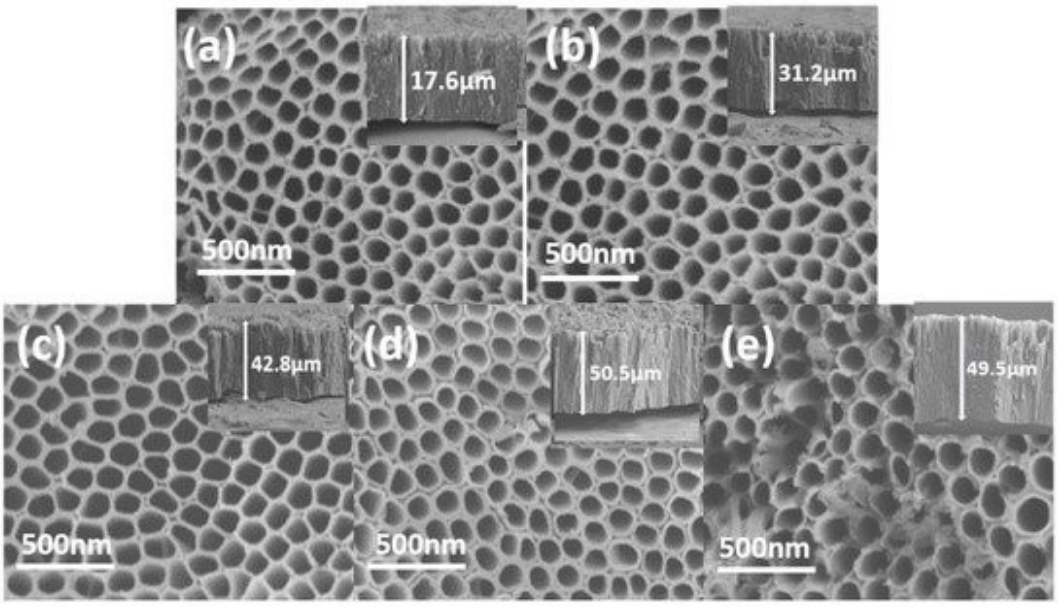

a
300 nm
b
300 nm
c
300 nm
d
e
1μm
f
300 nm

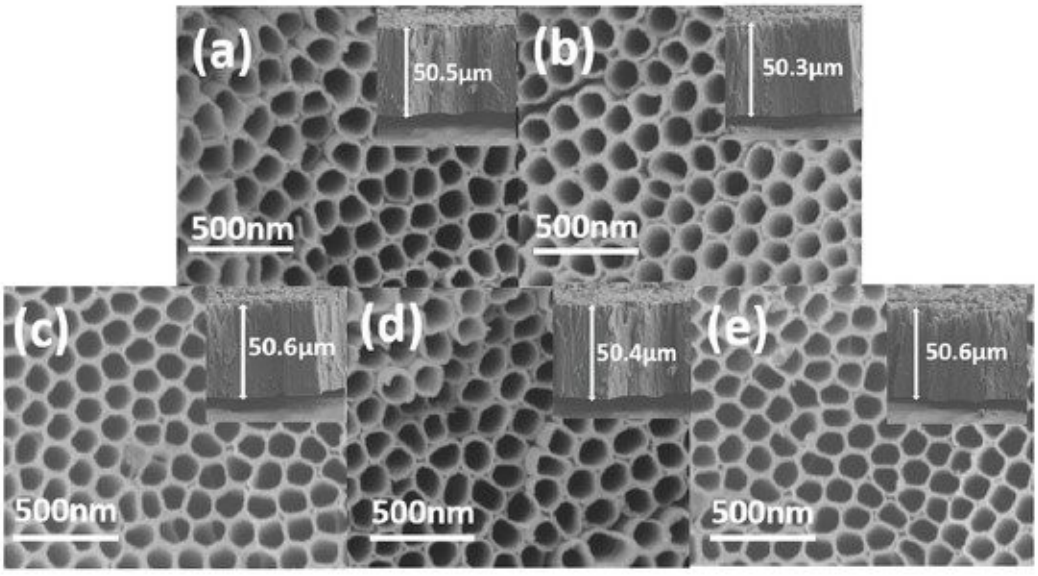

(a)
1 μm
(b)
1 μm
(c)
100 nm
(d)
100 nm

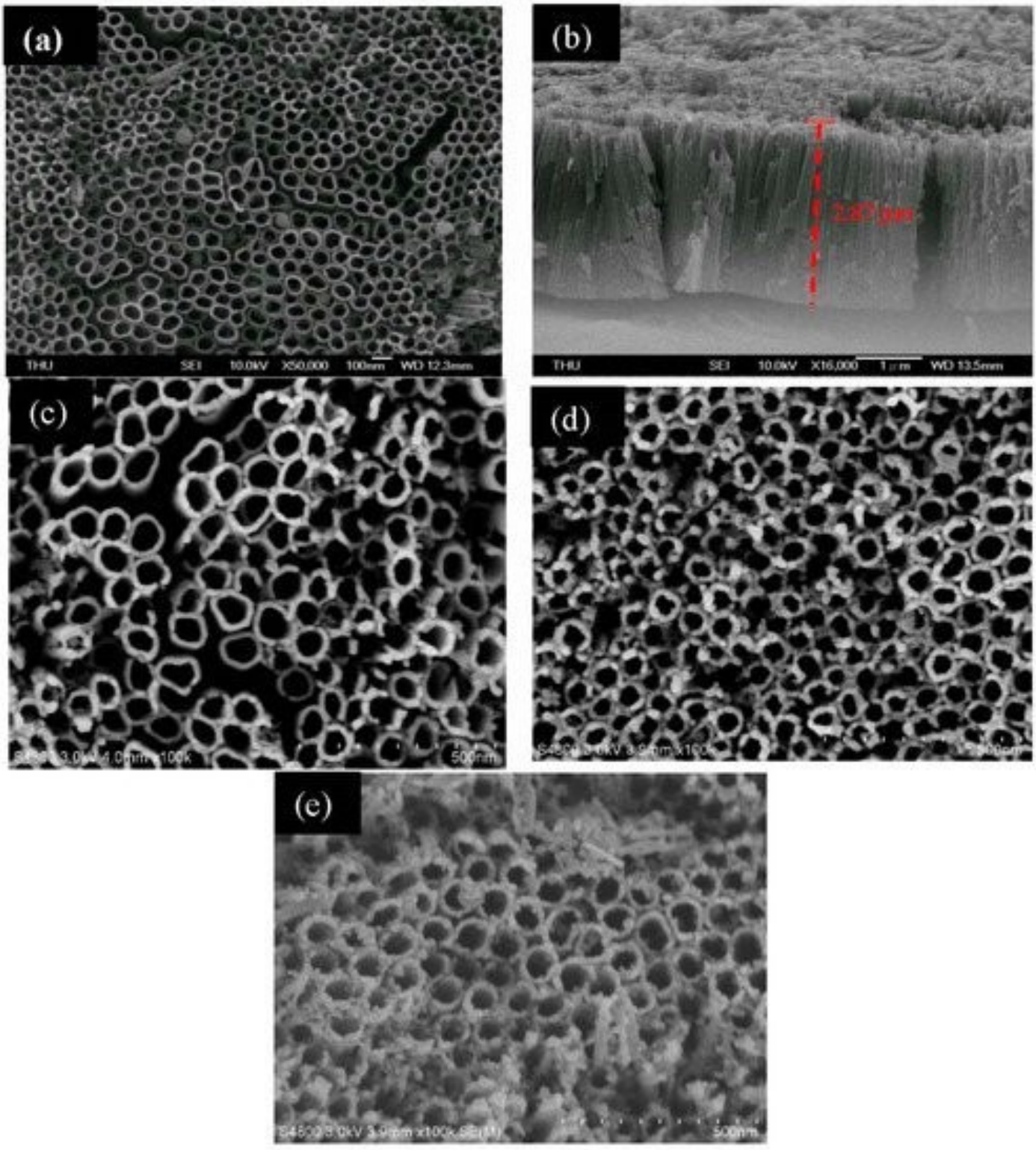

(a)
Ti
O
C
Cu
Ti
Cu
Cu
3000
2500
2000
1500
1000
500
0
0 1 2 3 4 5 6 7 8 9 10
Key
(b)
100nm
(c)
d4
(211)
d3
(105)
d1
d2
(200)
(101)
(d)
0.35nm(101)
0.19nm(200)
5nm

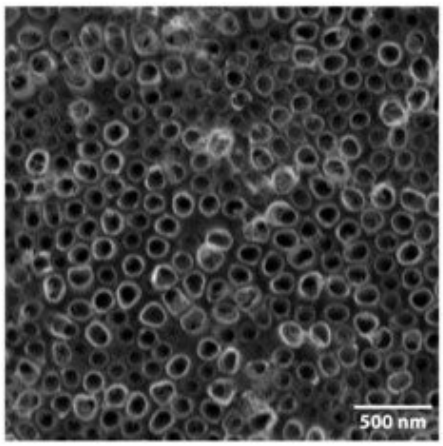

(a)
5μm
(b)
1μm
(c)
500nm
(d)
500nm


(a)
18.6μm
500nm
(b)
29.4μm
500nm
(c)
50.5μm
500nm
(d)
51.2μm
500nm
(e)
51.8μm
500nm

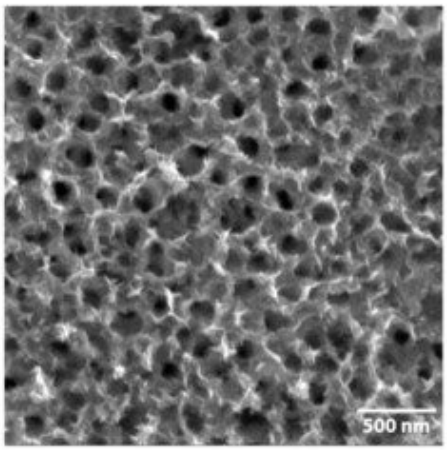

(a)
17.6μm
500nm
(b)
31.2μm
500nm
(c)
42.8μm
500nm
(d)
50.5μm
500nm
(e)
49.5μm
500nm


(a)
50.5μm
500nm
(b)
50.3μm
500nm
(c)
50.6μm
500nm
(d)
50.4μm
500nm
(e)
50.6μm
500nm

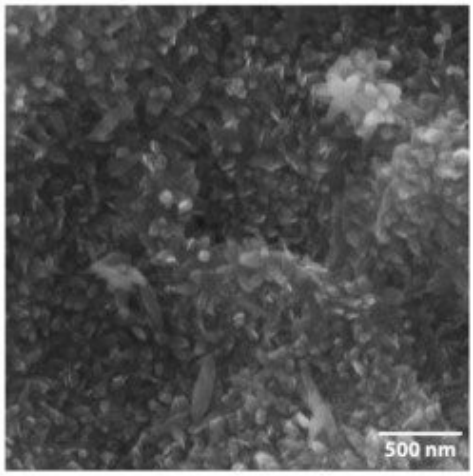

(a)
(b)
(c)
(d)
(e)



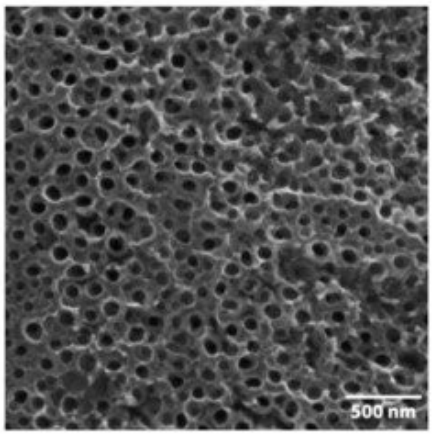
(a)



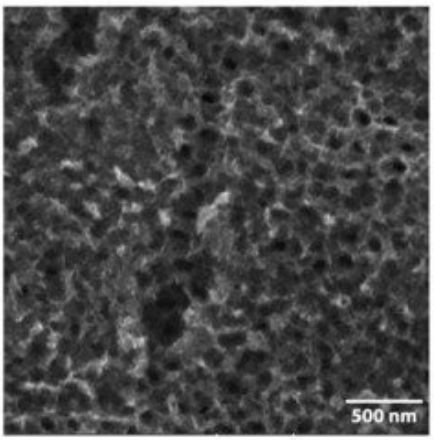
(b)



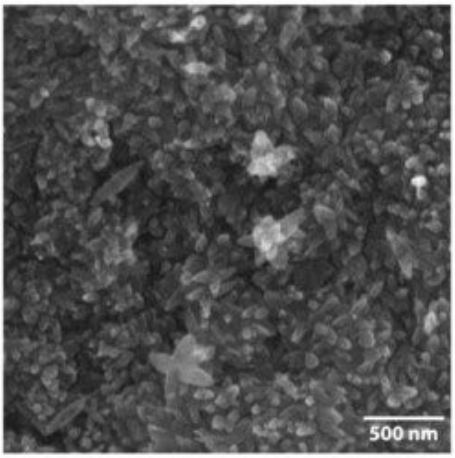
(c)



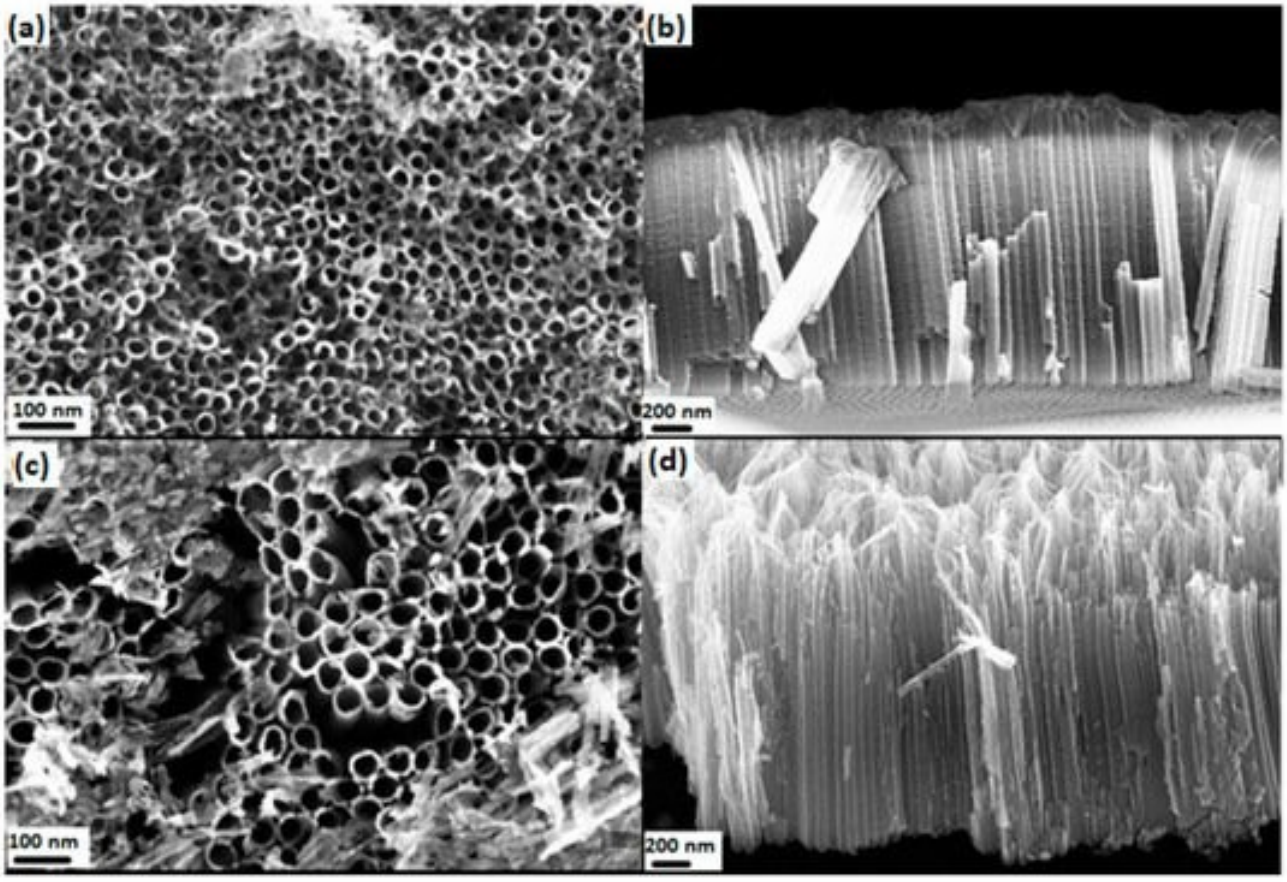
(a)

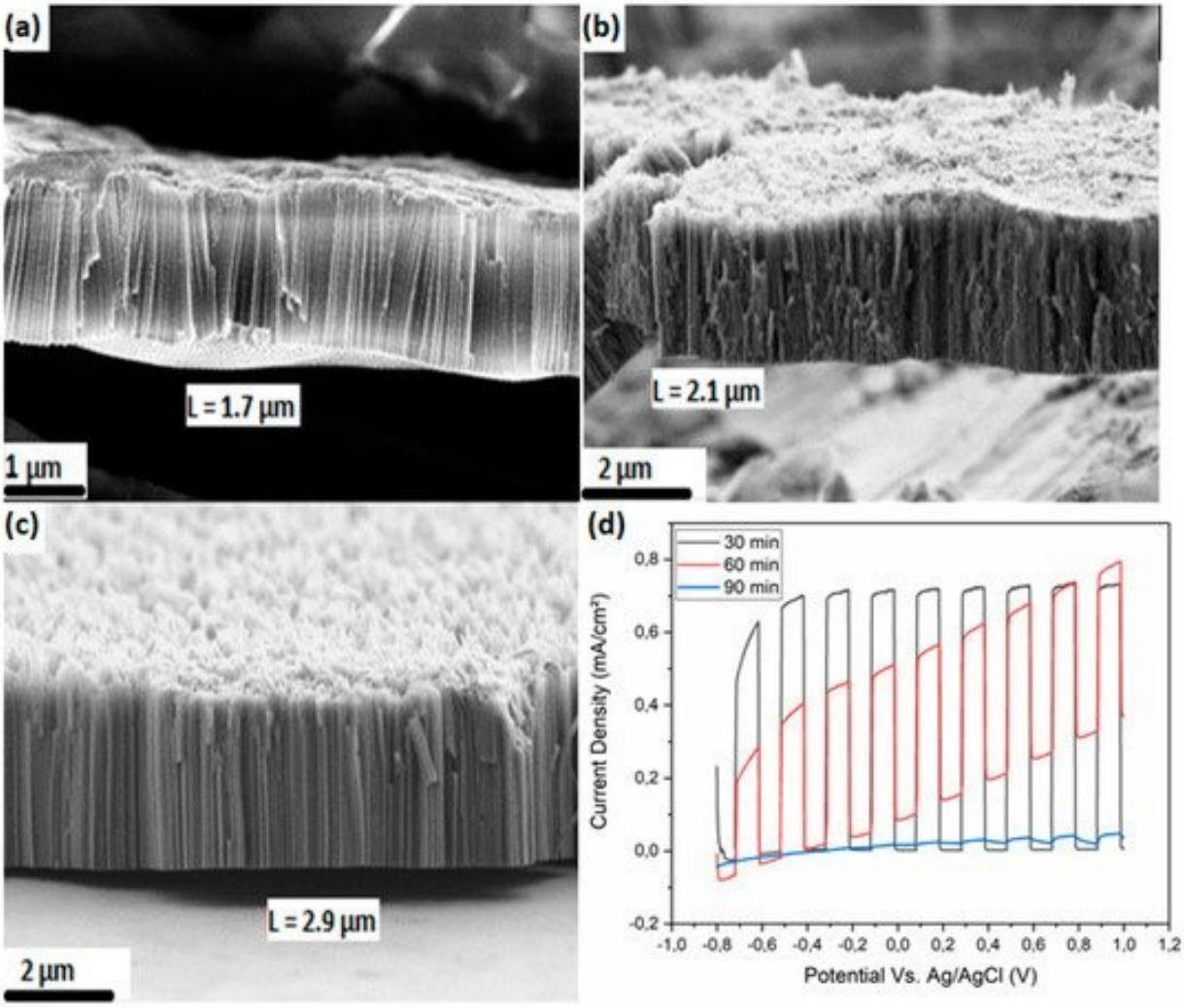


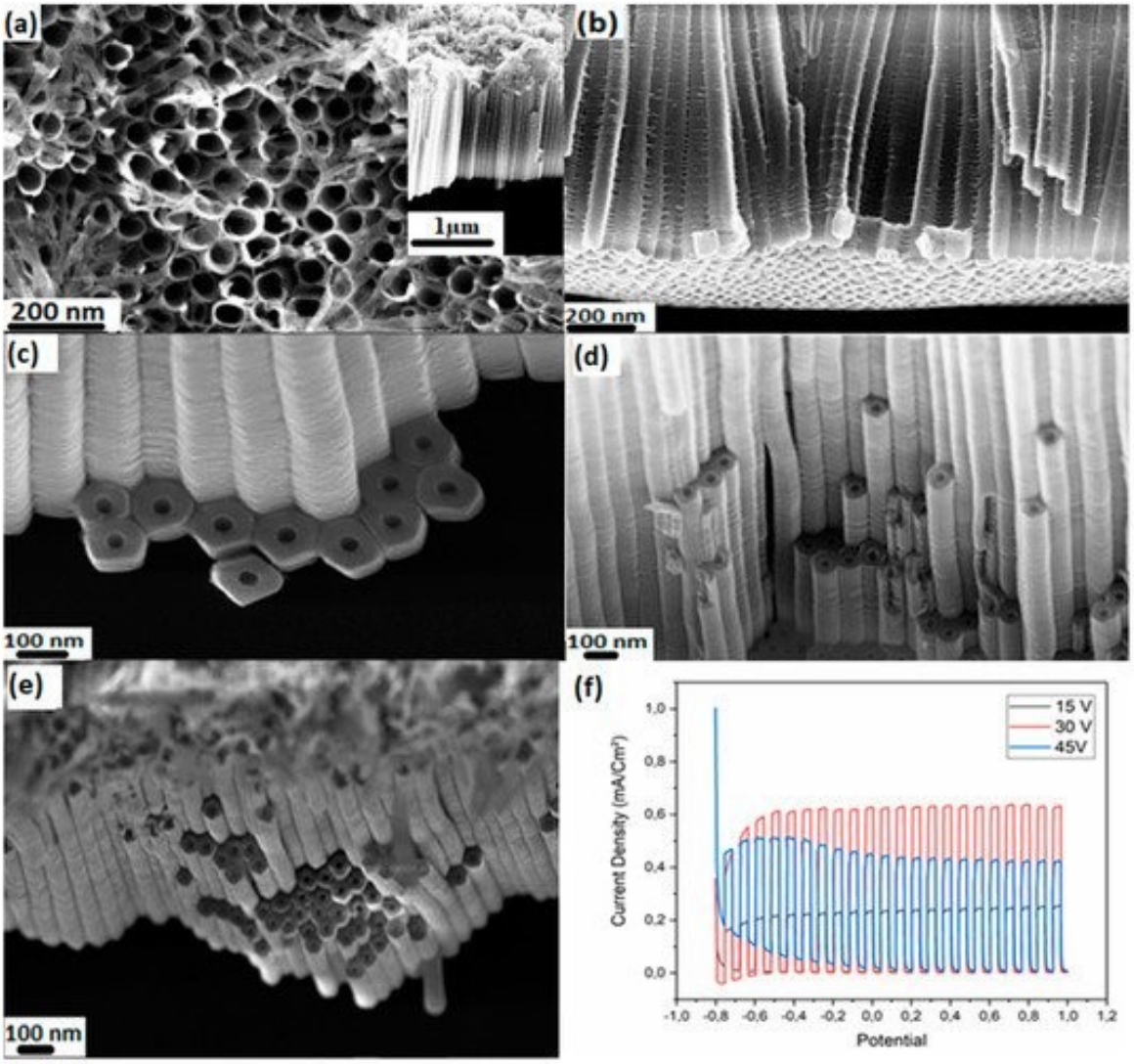
(b)

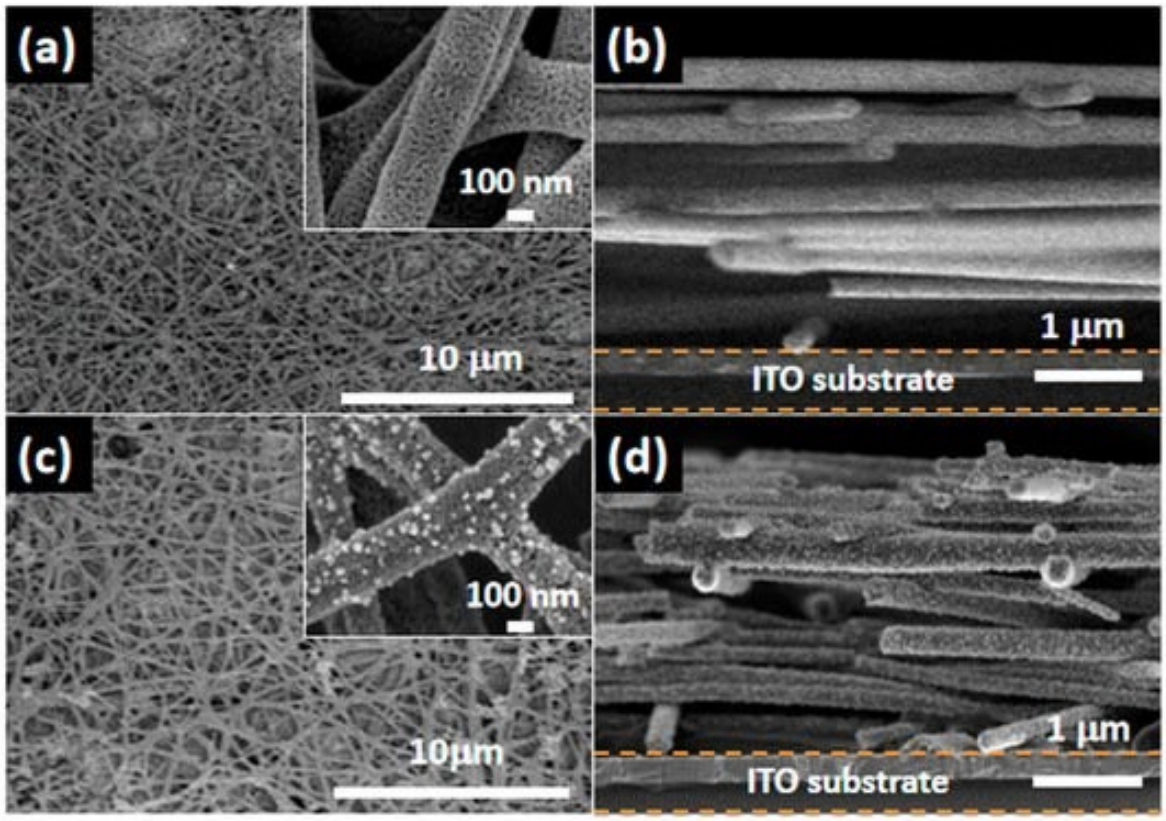


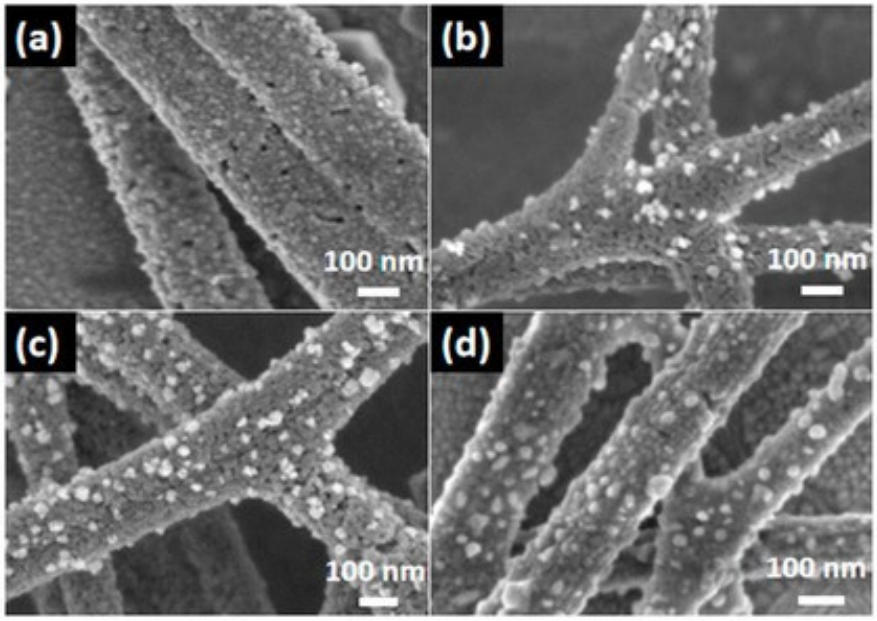
(c)

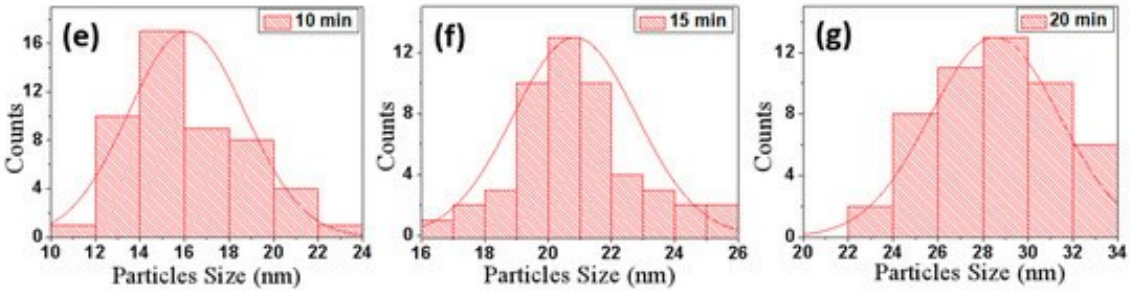

(a)
100 nm
(b)
200 nm
(c)
100 nm
(d)
200 nm

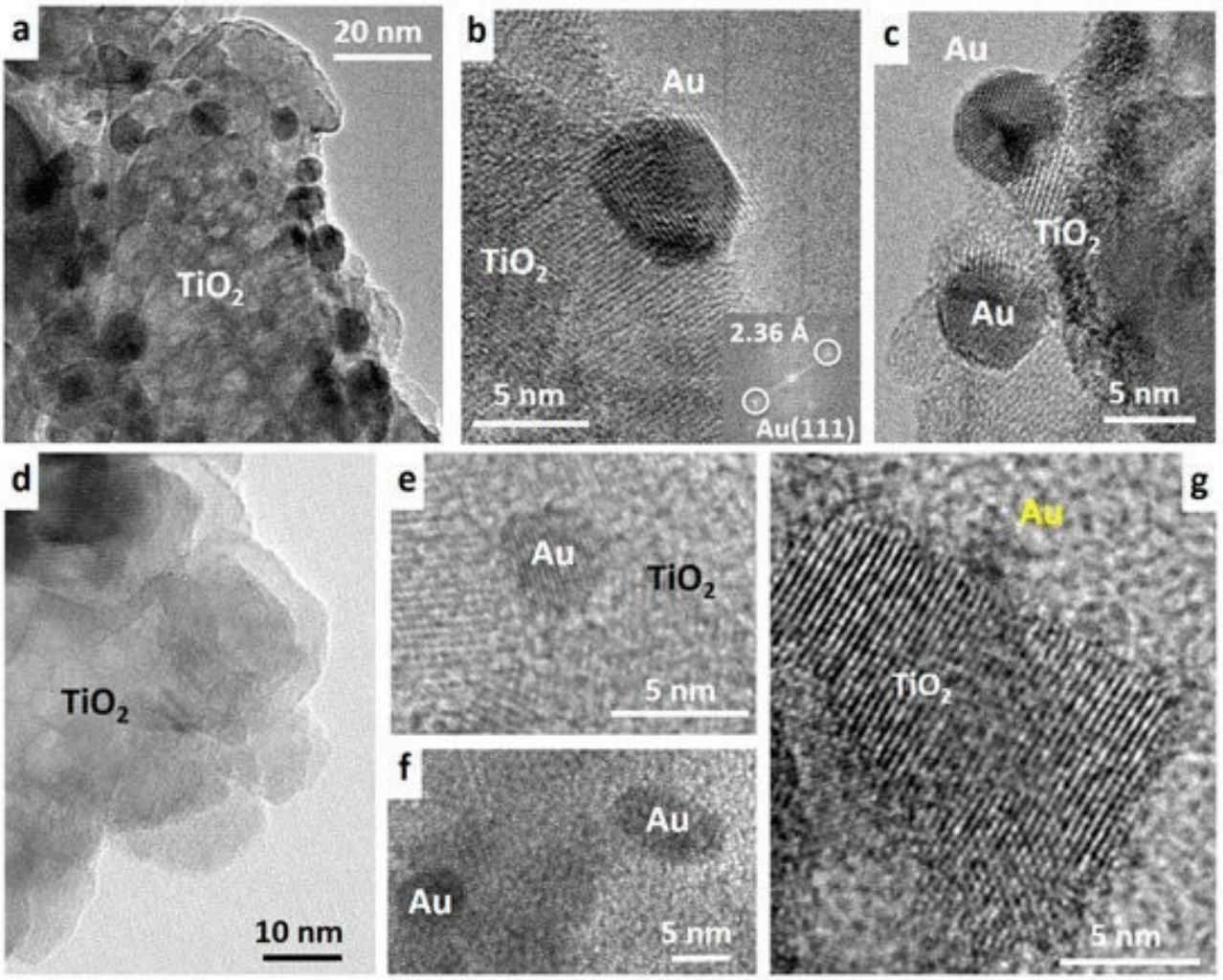

(a)
L = 1.7 µm
1 µm
(b)
L = 2.1 µm
2 µm
(c)
L = 2.9 µm
2 µm
(d)
30 min
60 min
90 min
Current Density (mA/cm²)
Potential Vs. Ag/AgCl (V)

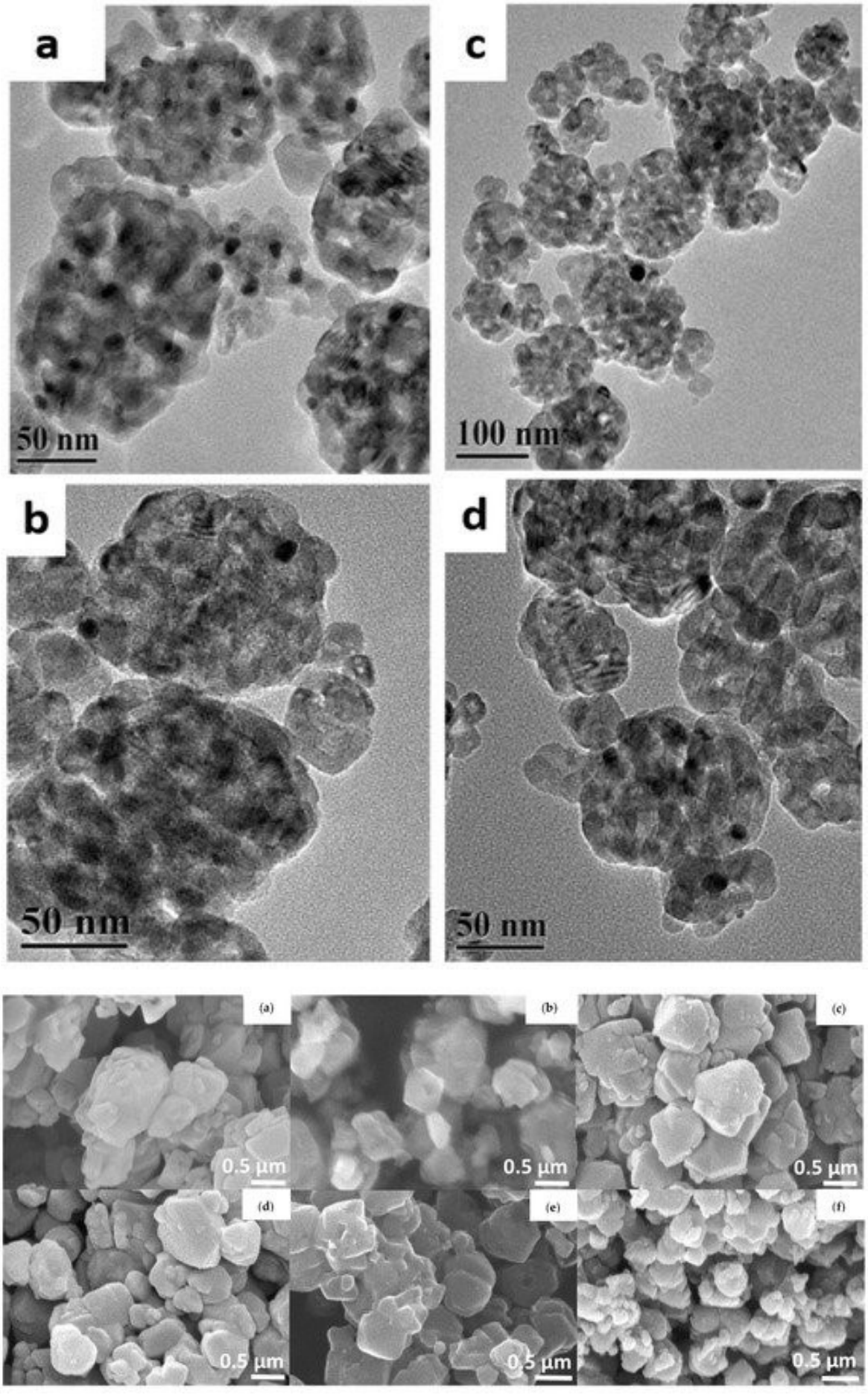

(a)
1μm
200 nm
(b)
200 nm
(c)
100 nm
(d)
100 nm
(e)
100 nm
(f)
15 V
30 V
45V
Current Density (mA/Cm²)
Potential

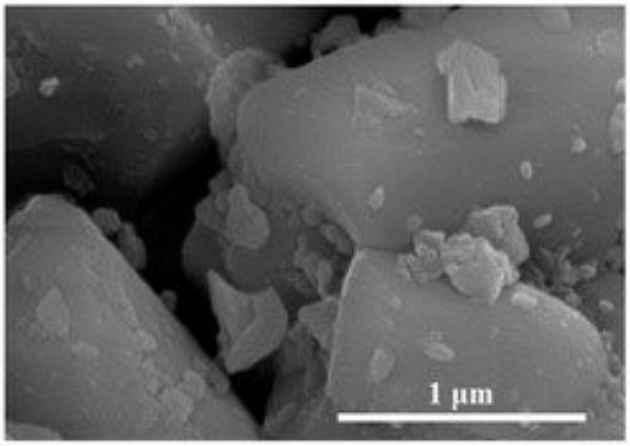

(a)
100 nm
10 μm
(b)
1 μm
ITO substrate
(c)
100 nm
10μm
(d)
1 μm
ITO substrate


(a)
100 nm
(b)
100 nm
(c)
100 nm
(d)
100 nm

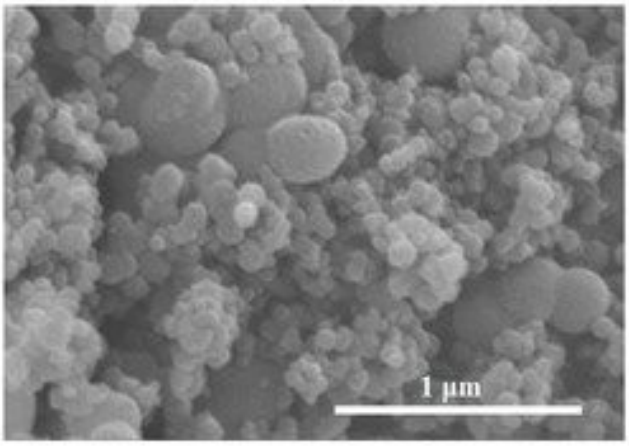

(e)
10 min
Counts
Particles Size (nm)
(f)
15 min
Counts
Particles Size (nm)
(g)
20 min
Counts
Particles Size (nm)


a
20 nm
TiO2
b
Au
TiO2
2.36 Å
5 nm
Au(111)
c
Au
TiO2
Au
5 nm
d
TiO2
10 nm
e
Au
TiO2
5 nm
f
Au
Au
5 nm
g
Au
TiO2
5 nm

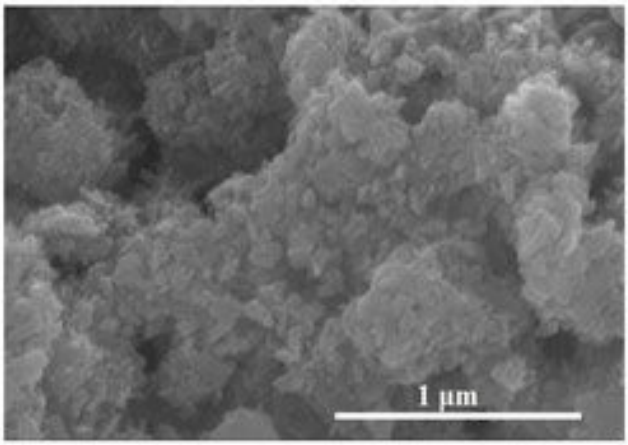

a
50 nm
c
100 nm
b
50 nm
d
50 nm
(a)
0.5 µm
(b)
0.5 µm
(c)
0.5 µm
(d)
0.5 µm
(e)
0.5 µm
(f)
0.5 µm



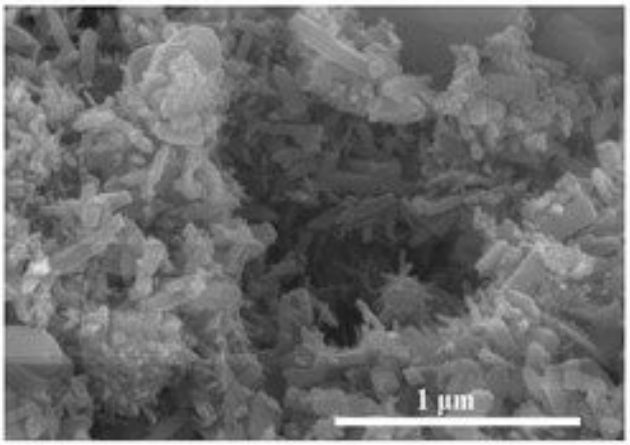
(a)



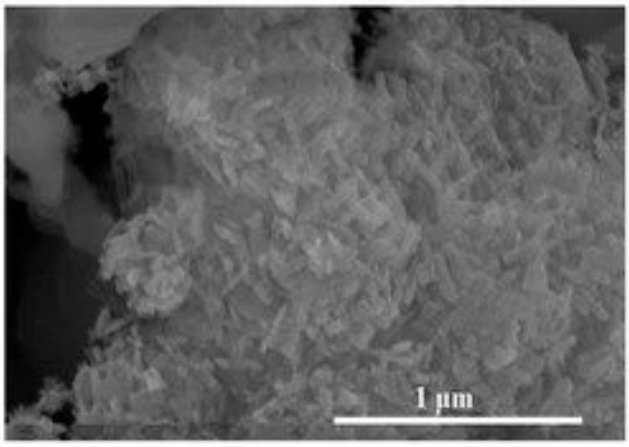
(b)



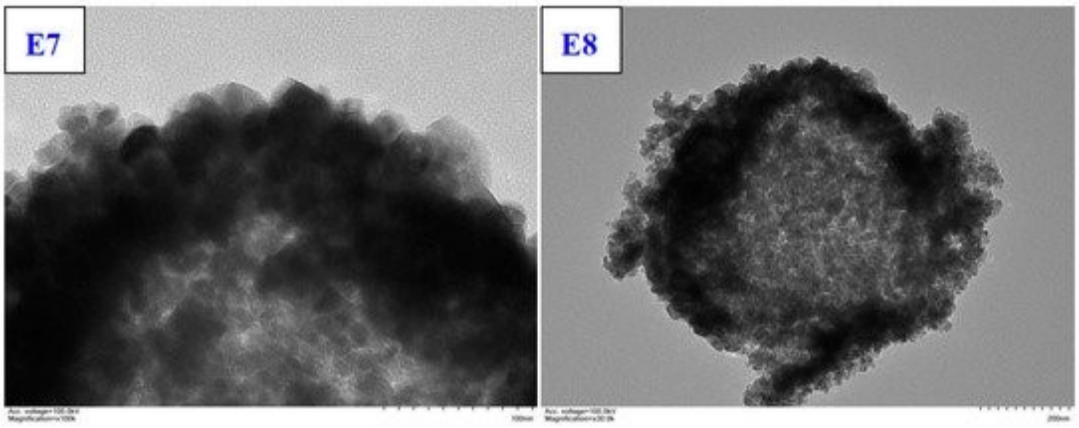
(c)

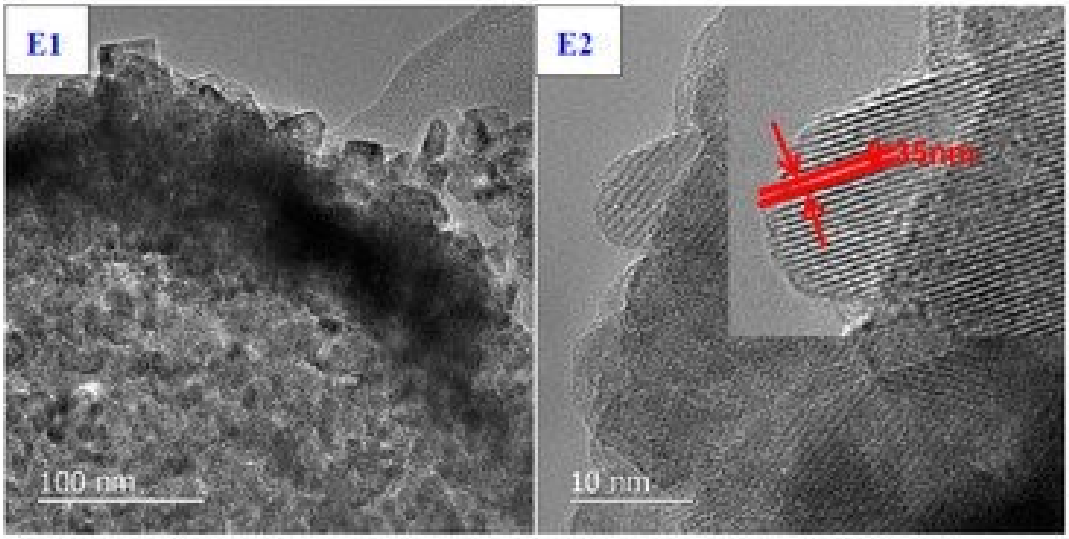


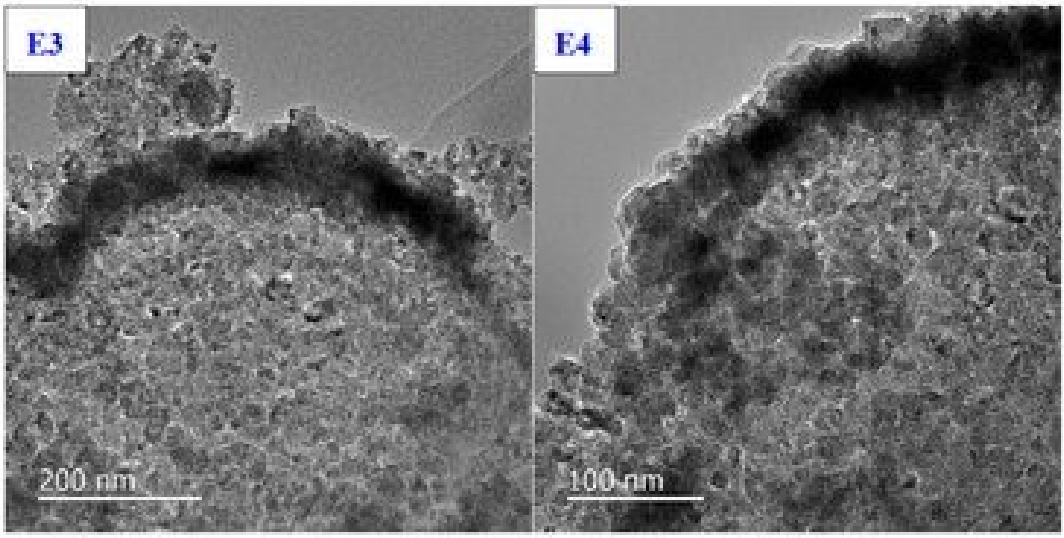
(d)

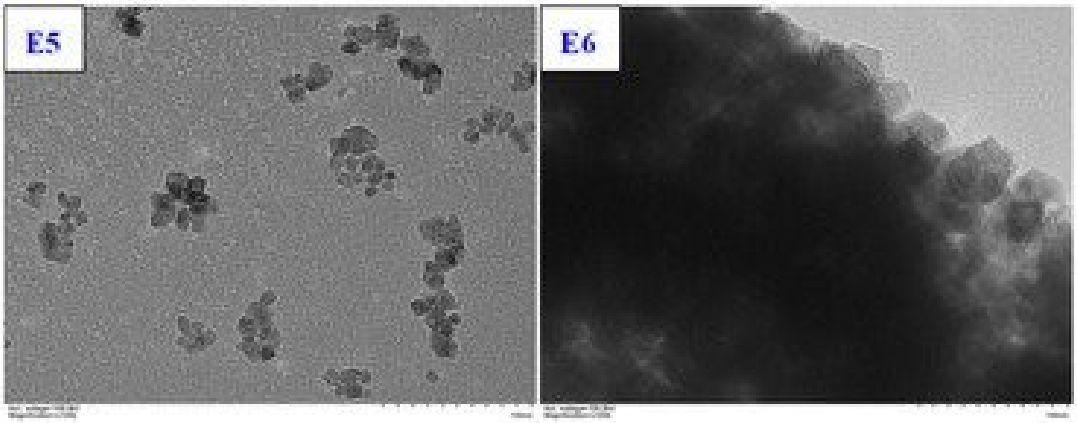


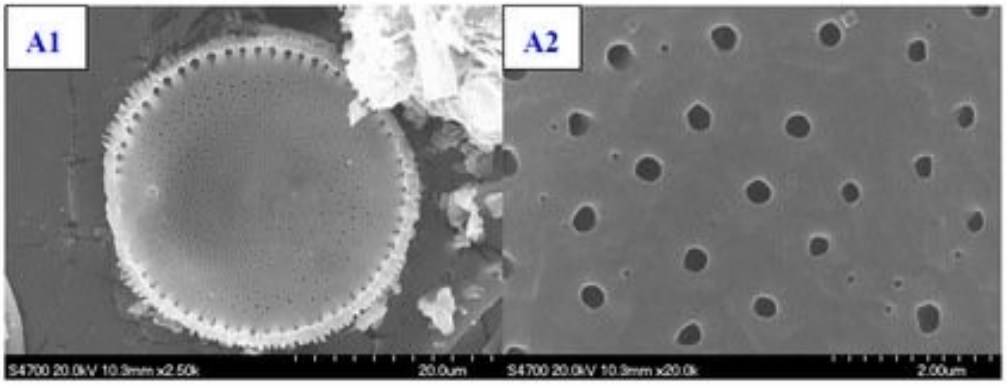
(e)

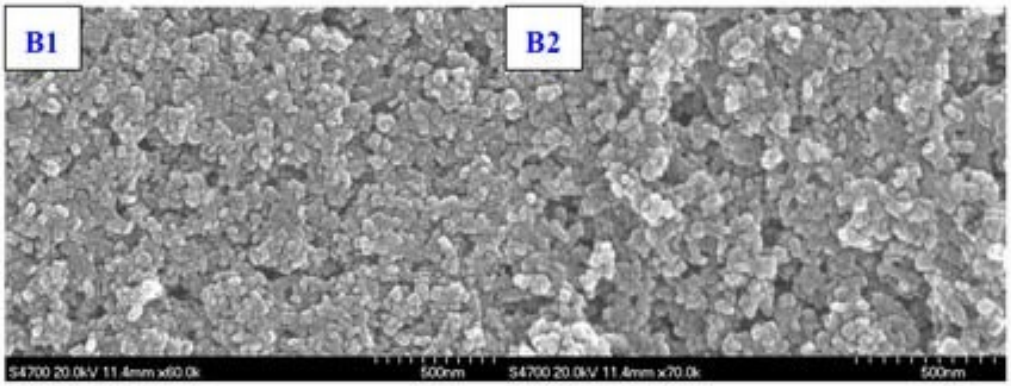

E7
E8

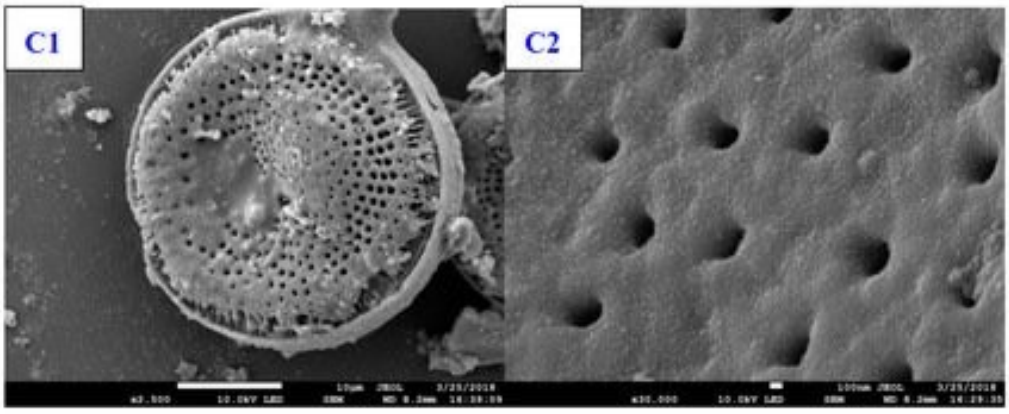

E1
100 nm
E2
0.35nm
10 nm

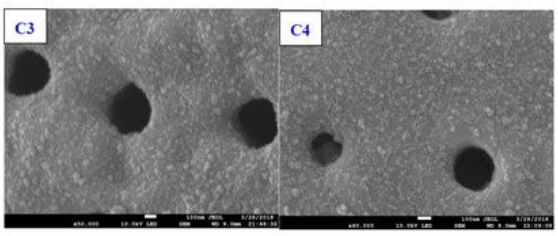

E3
200 nm
E4
100 nm

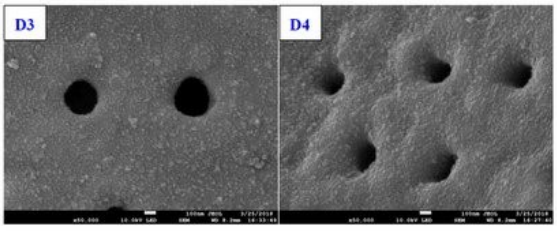

E5
E6

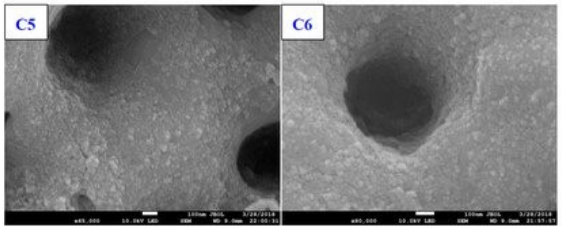

A1
A2
S4700 20.0kV 10.3mm x2.50k
20.0um
S4700 20.0kV 10.3mm x20.0k
2.00um

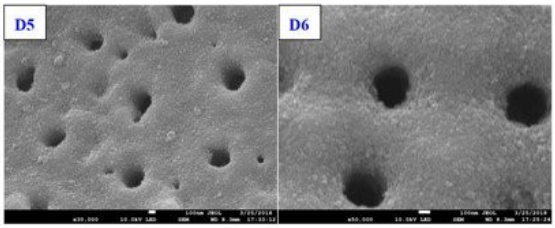

B1
B2
S4700 20.0kV 11.4mm x60.0k
500nm
S4700 20.0kV 11.4mm x70.0k
500nm

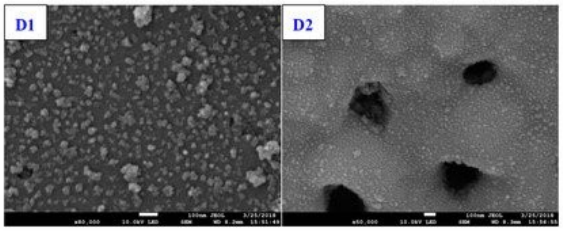

C1
C2

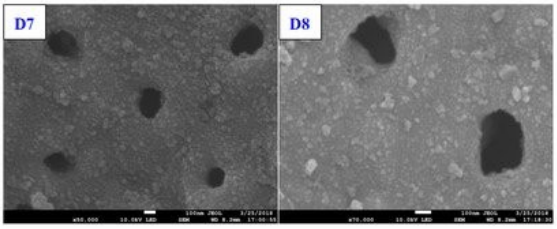

C3
C4

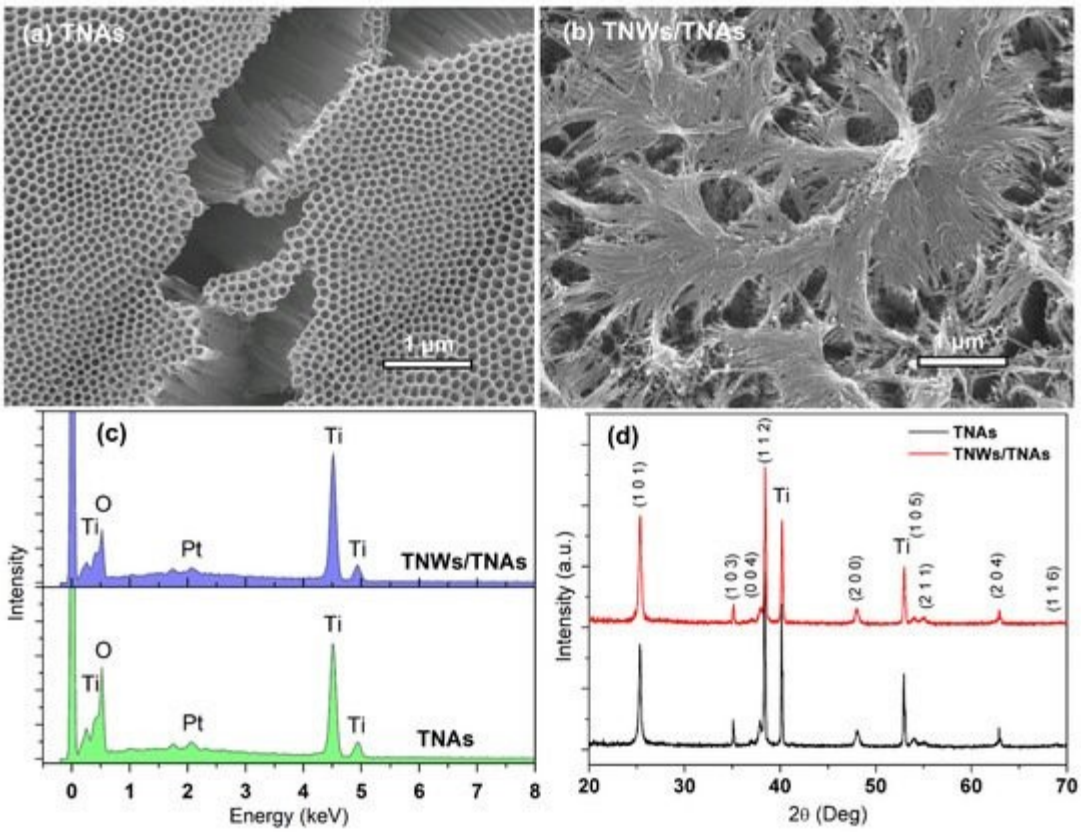

D3
D4

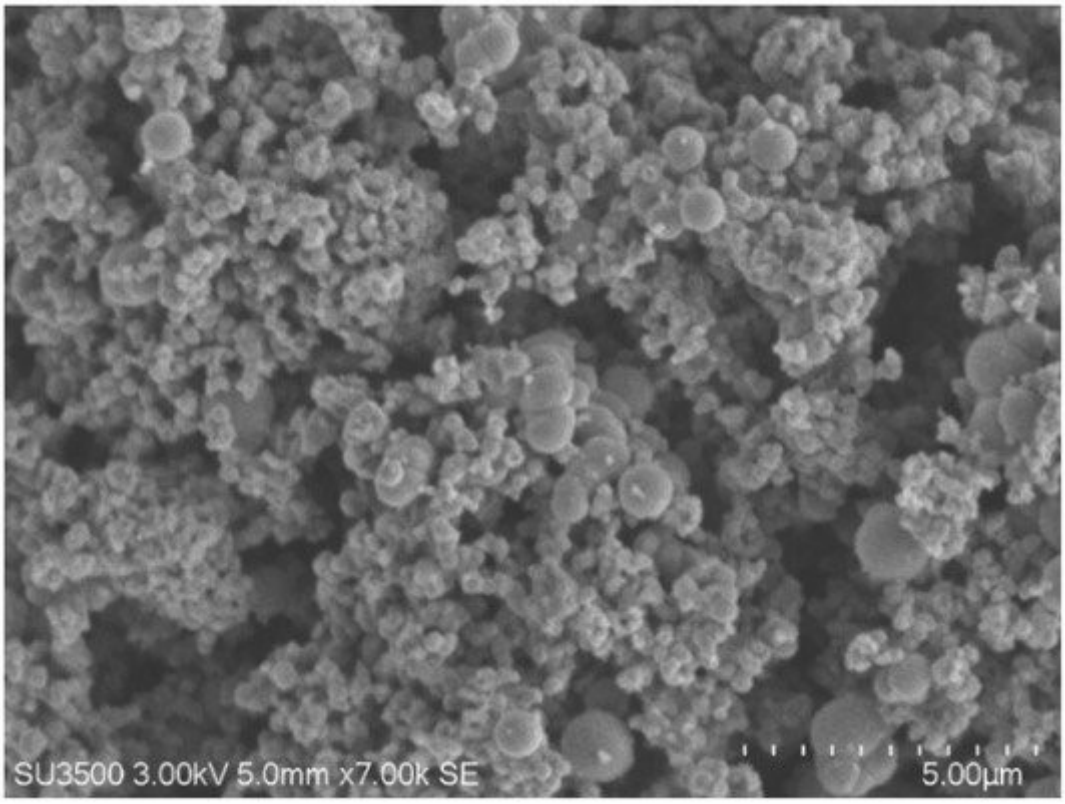

C5
C6


D5
D6


D1
D2

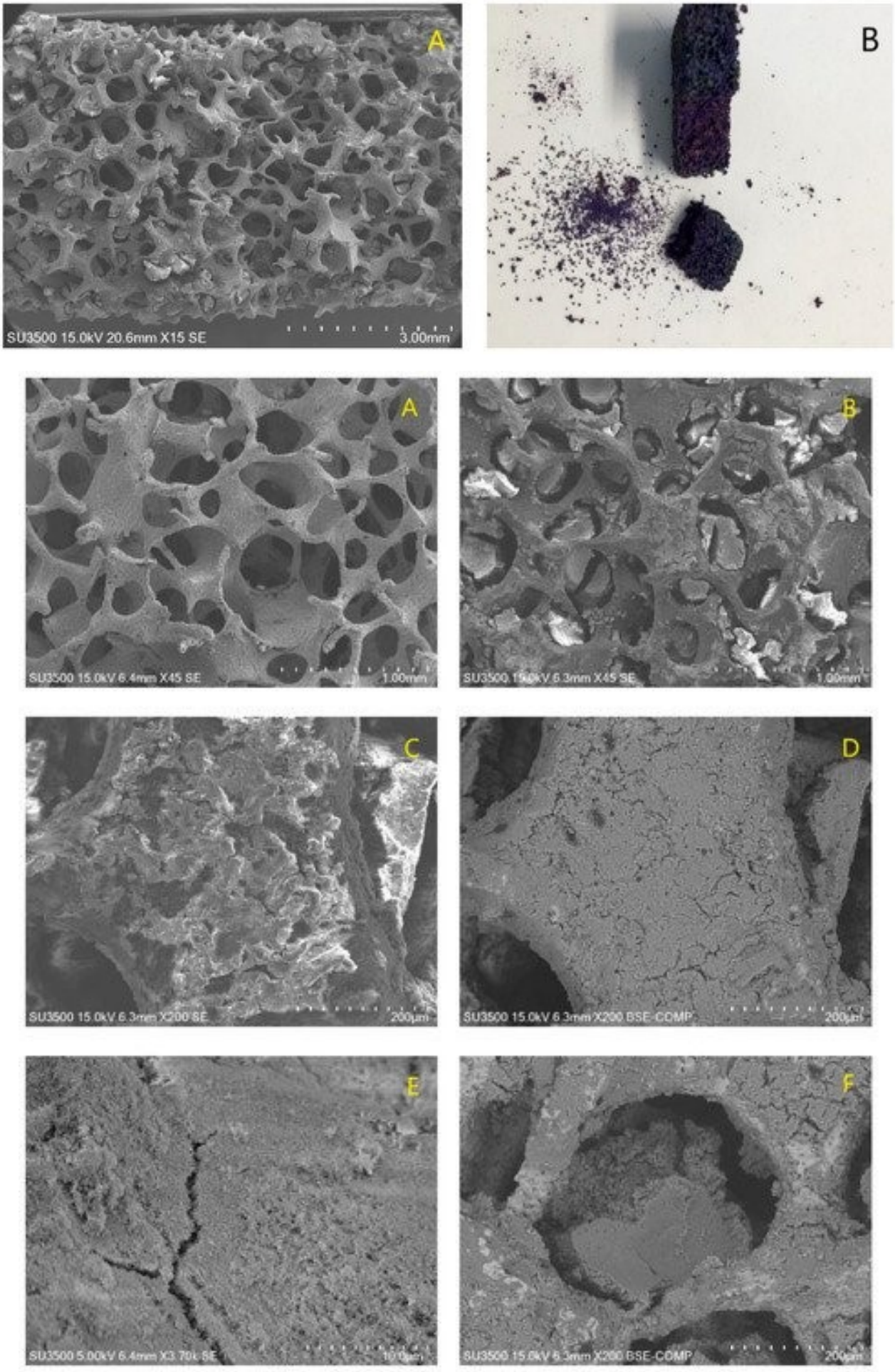

D7
D8





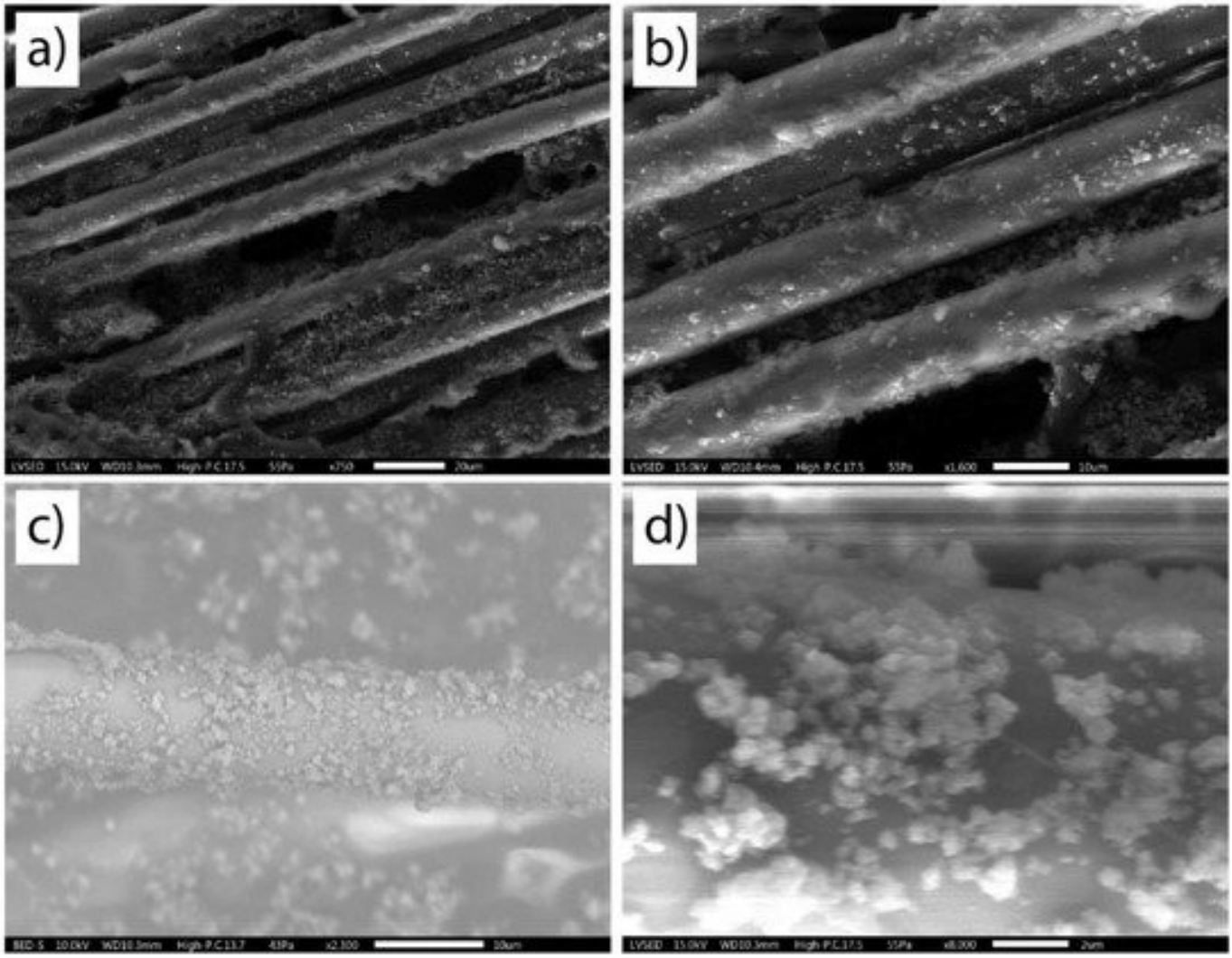
<TiO2/SiO2>:

<TiO2/Stainless-steel:

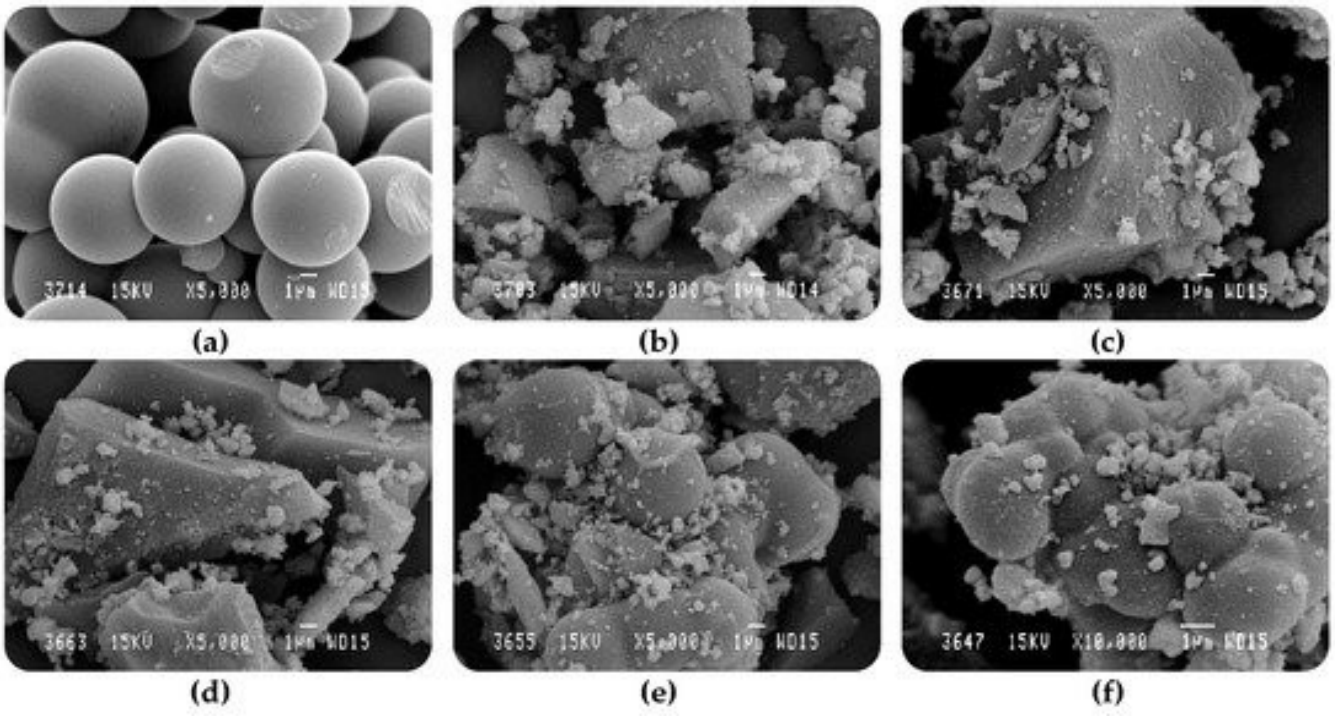


TIO2/Stainless-steel >

<TIO2/Fiberglass

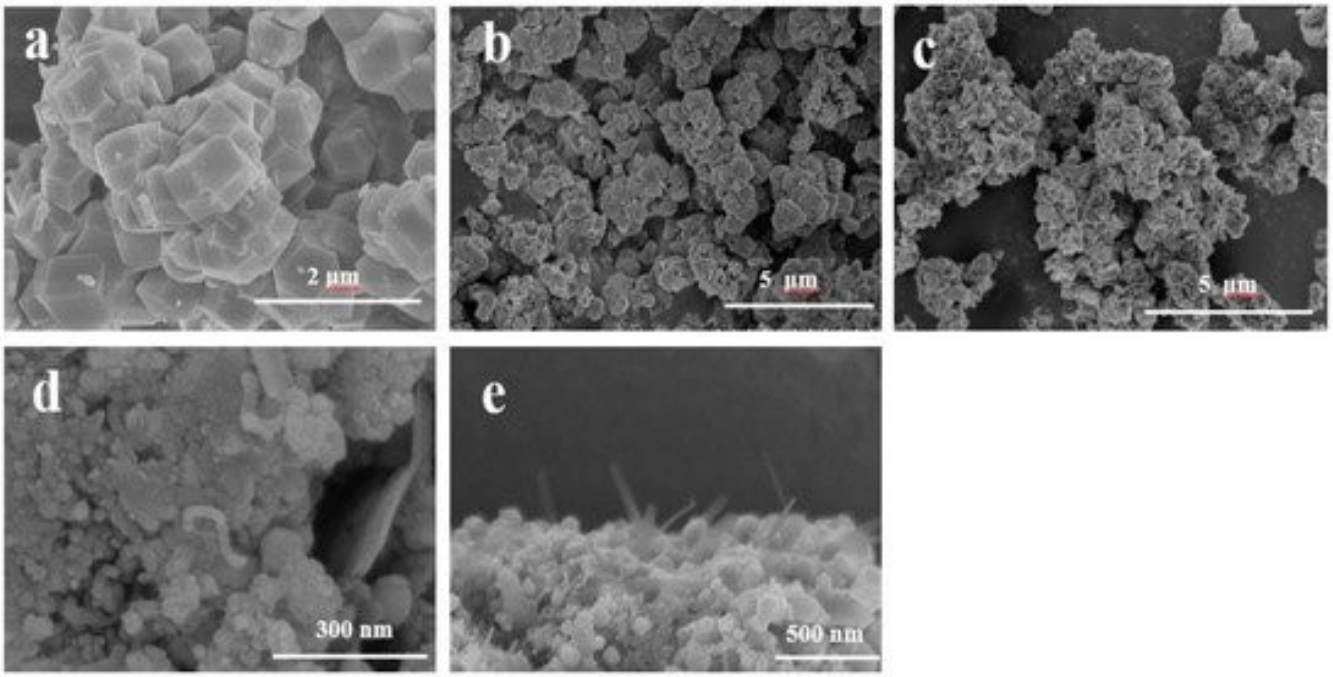


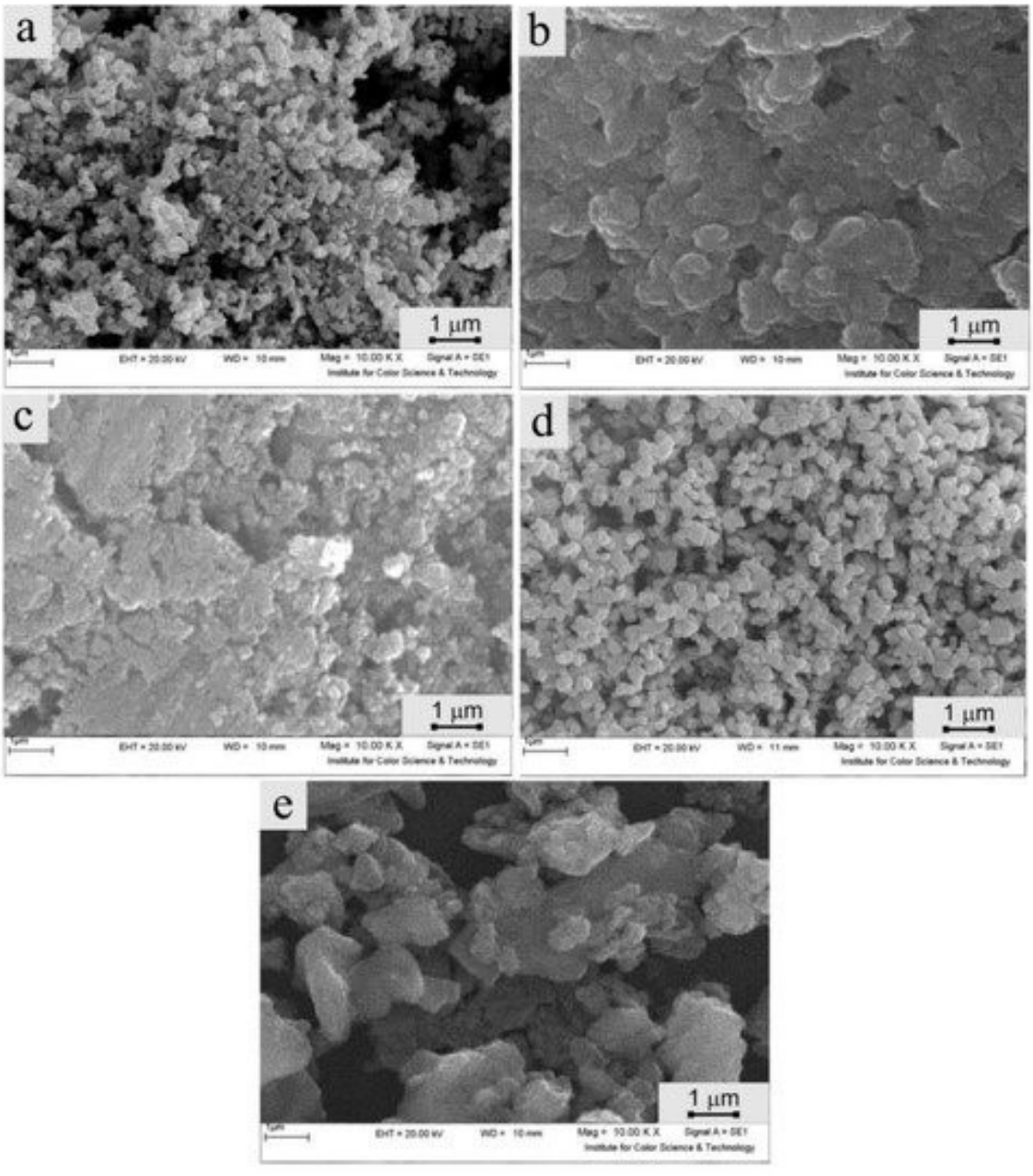
TiO2/fiberglass>

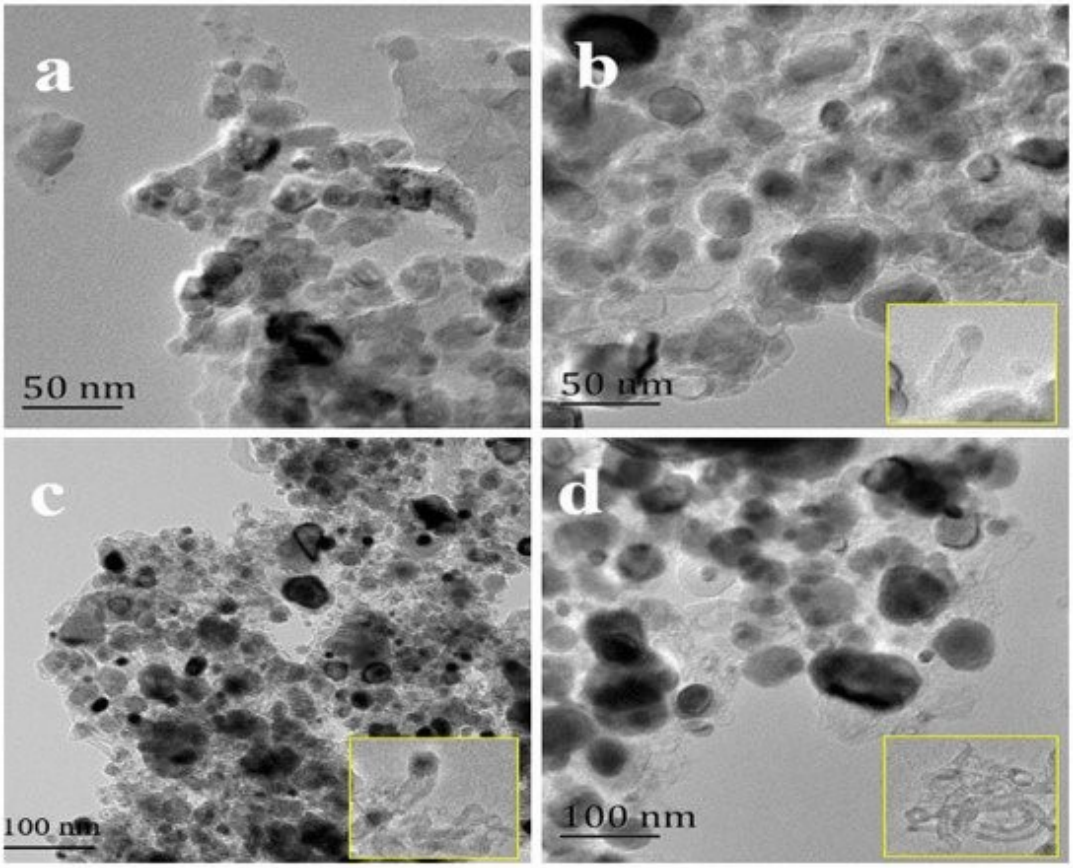


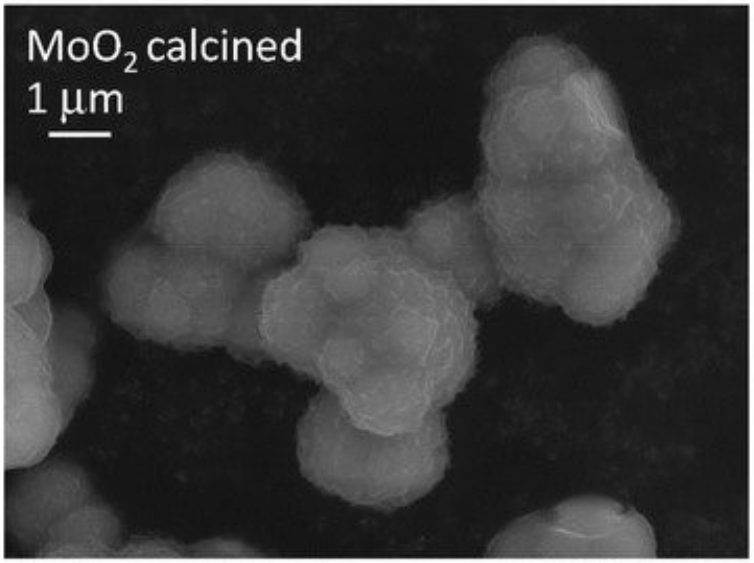
Ti]

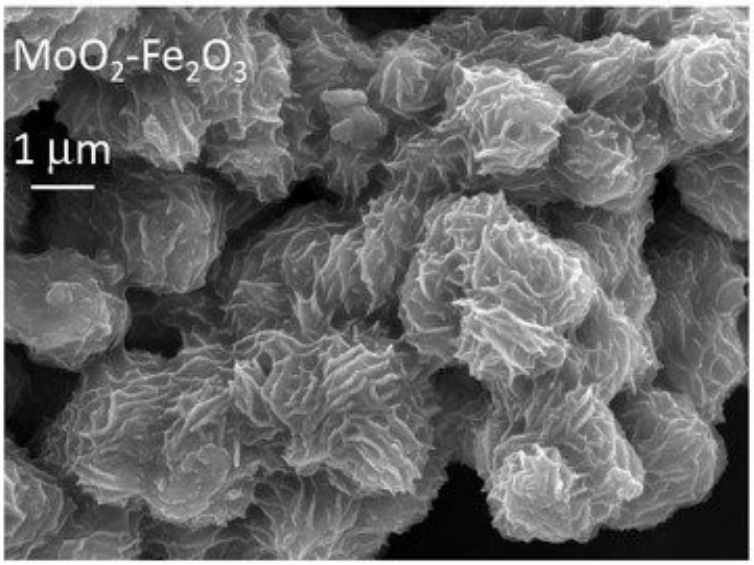
[Fe

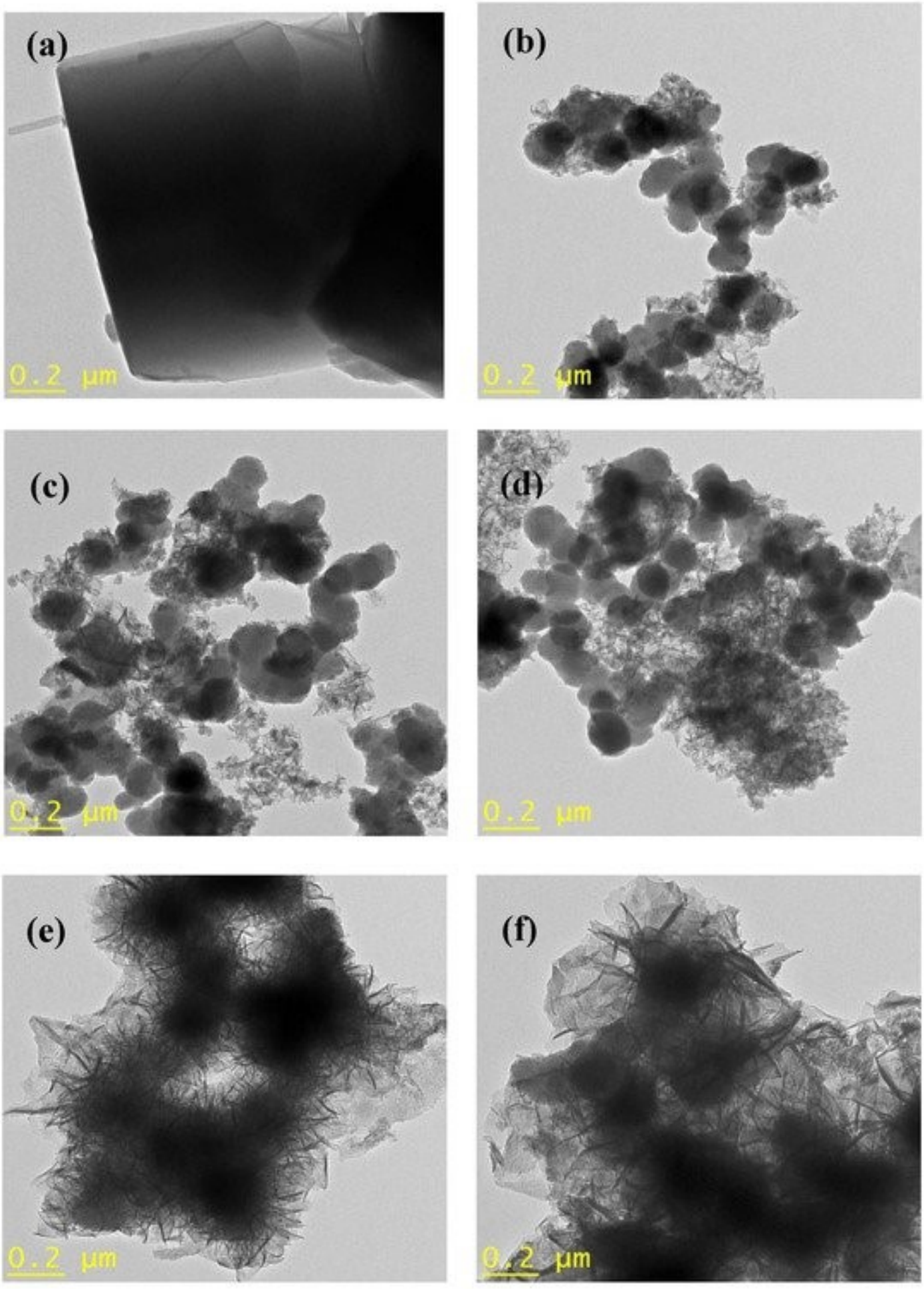

a
2 μm
b
5 μm
c
5 μm
d
300 nm
e
500 nm

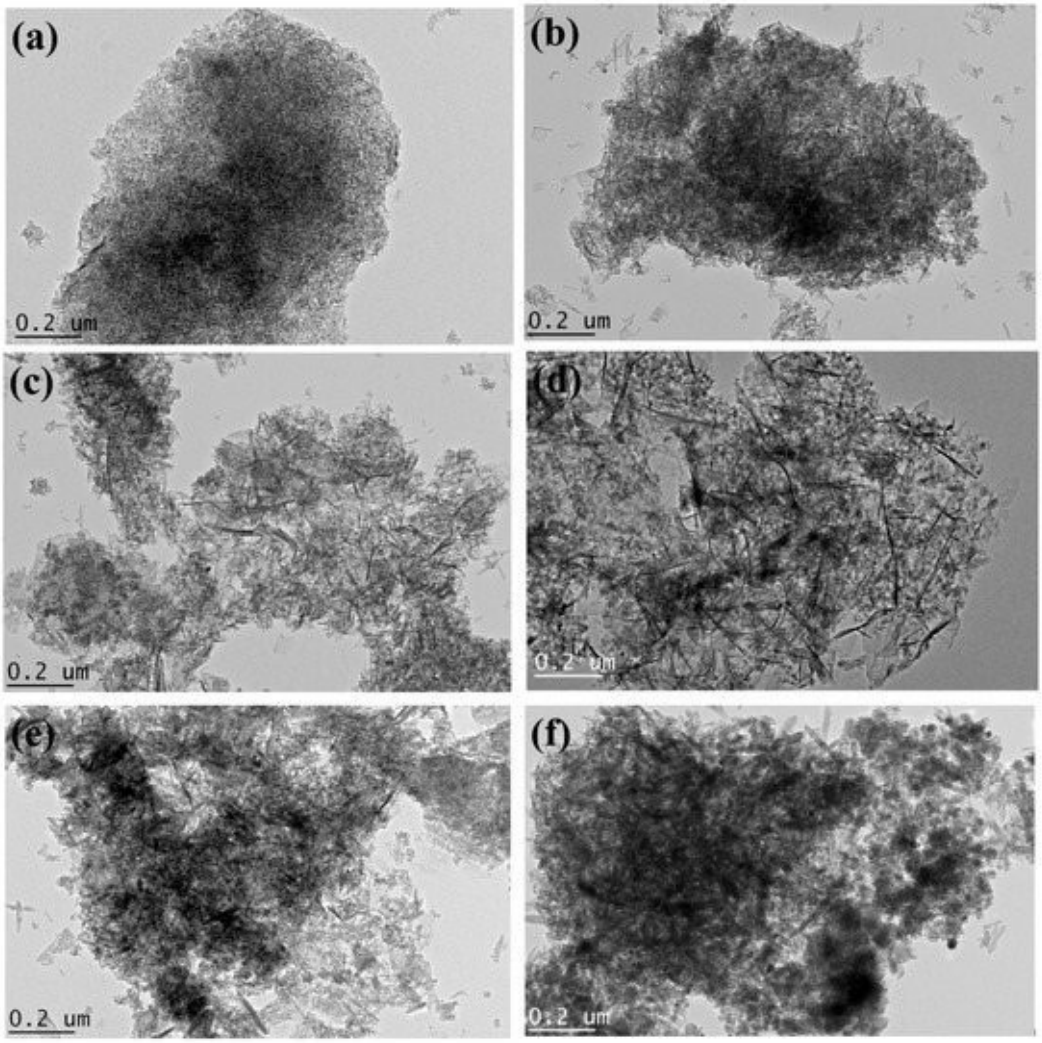

a
1 μm
b
1 μm
c
1 μm
d
1 μm
e
1 μm

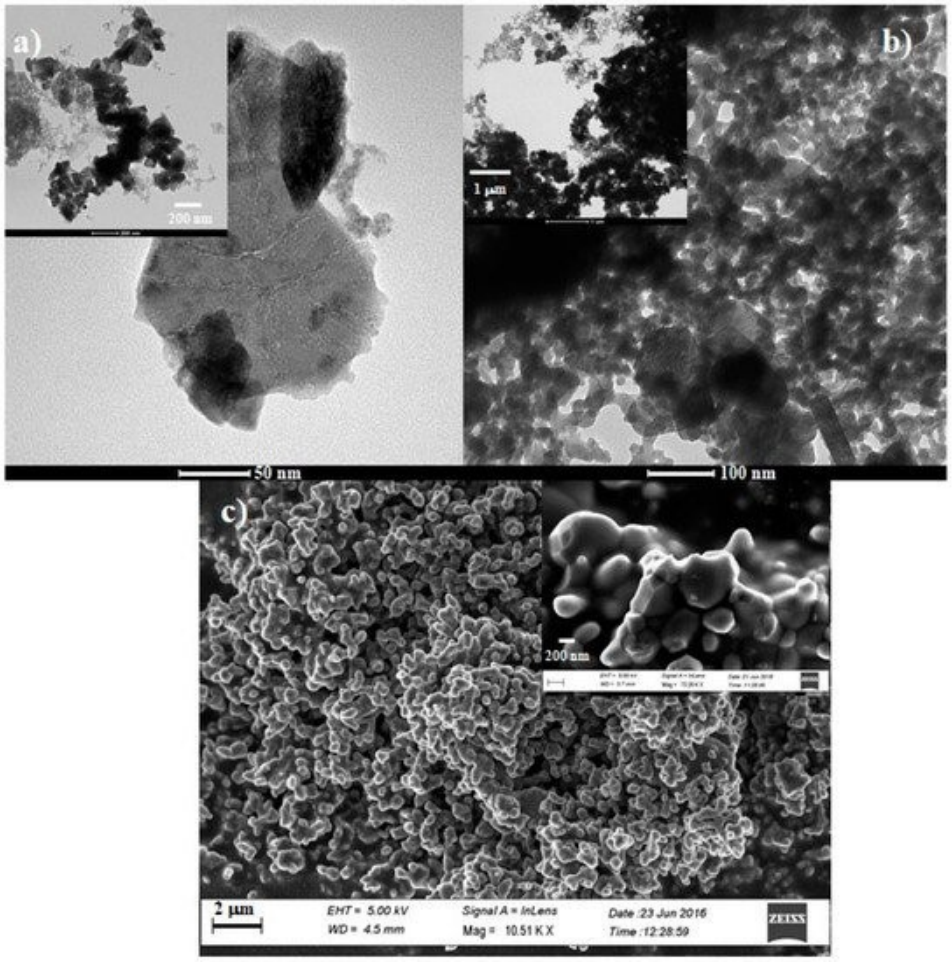

a
50 nm
b
50 nm
c
100 nm
d
100 nm


MoO2 calcined
1 µm


MoO2-Fe2O3
1 µm

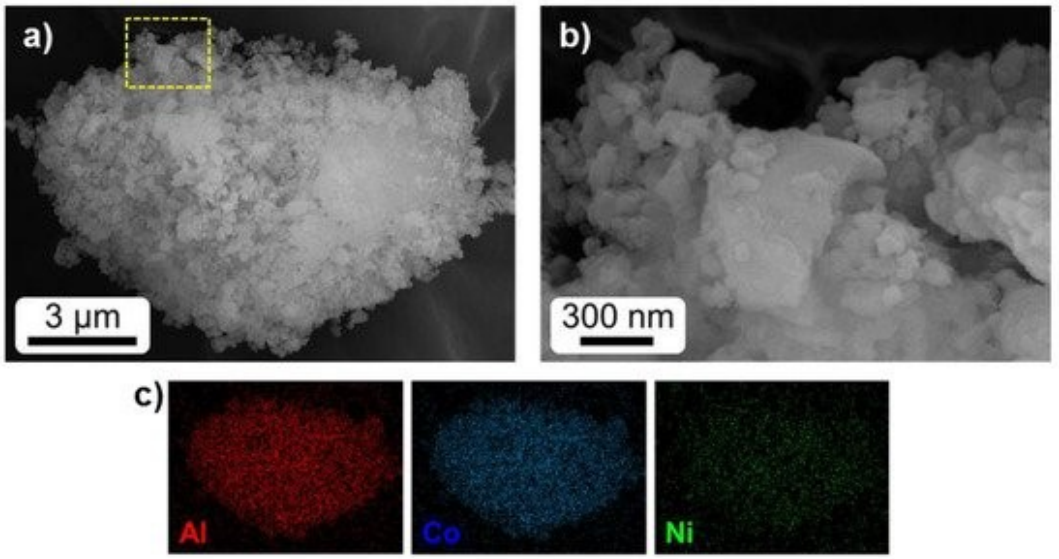

(a)
0.2 µm
(b)
0.2 µm
(c)
0.2 µm
(d)
0.2 µm
(e)
0.2 µm
(f)
0.2 µm

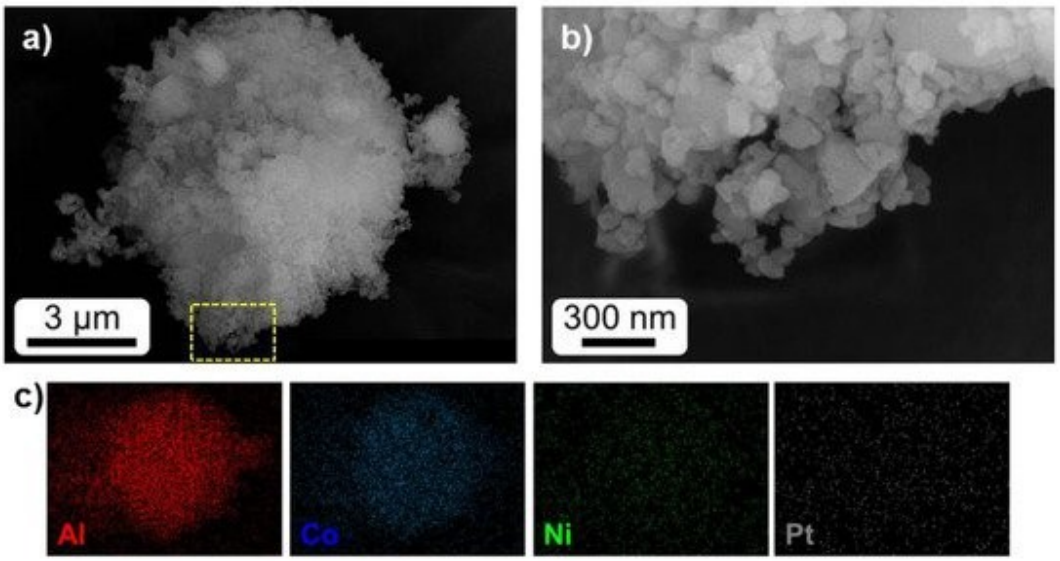

(a)
0.2 um
(b)
0.2 um
(c)
0.2 um
(d)
0.2 um
(e)
0.2 um
(f)
0.2 um

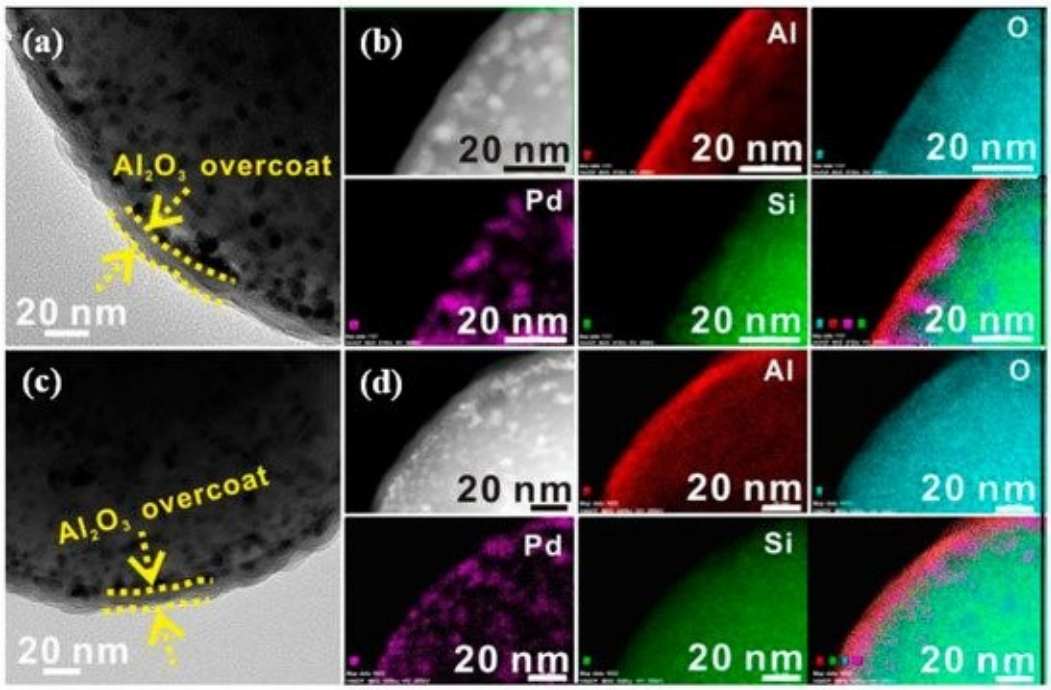

a)
200 nm
b)
1 µm
50 nm
100 nm
c)
200 nm
2 µm
EHT = 5.00 kV
WD = 4.5 mm
Signal A = InLens
Mag = 10.51 K X
Date :23 Jun 2016
Time :12:28:59
ZEISS

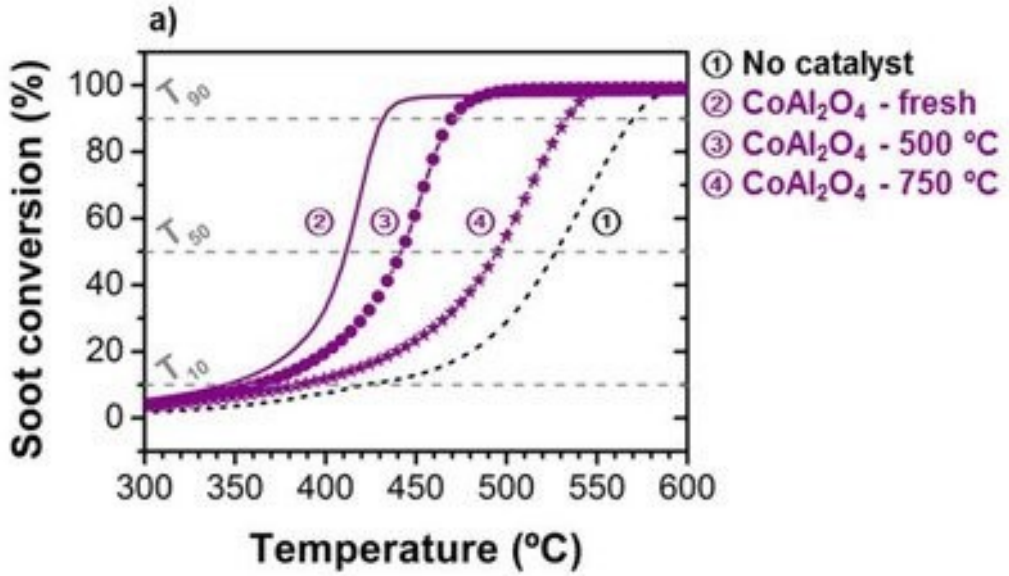
Fe]

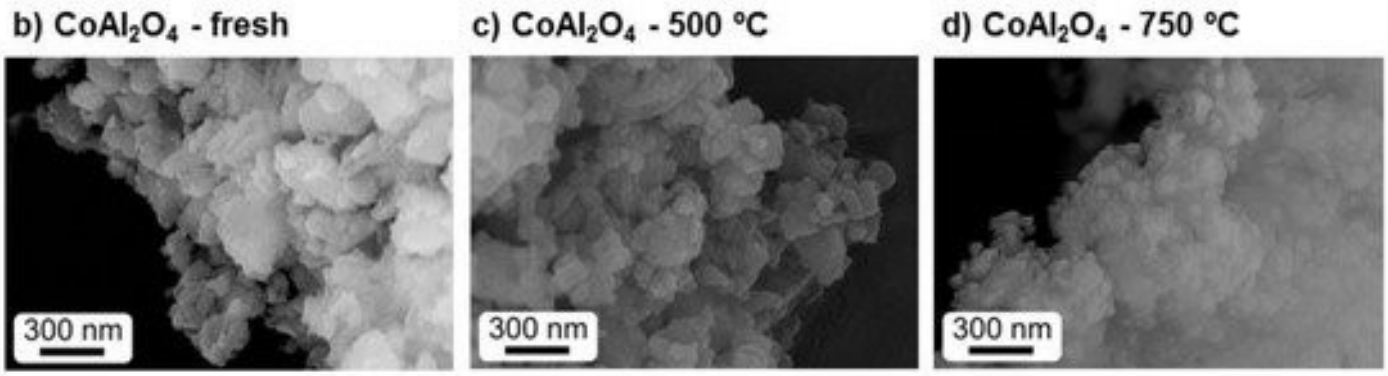
[A]

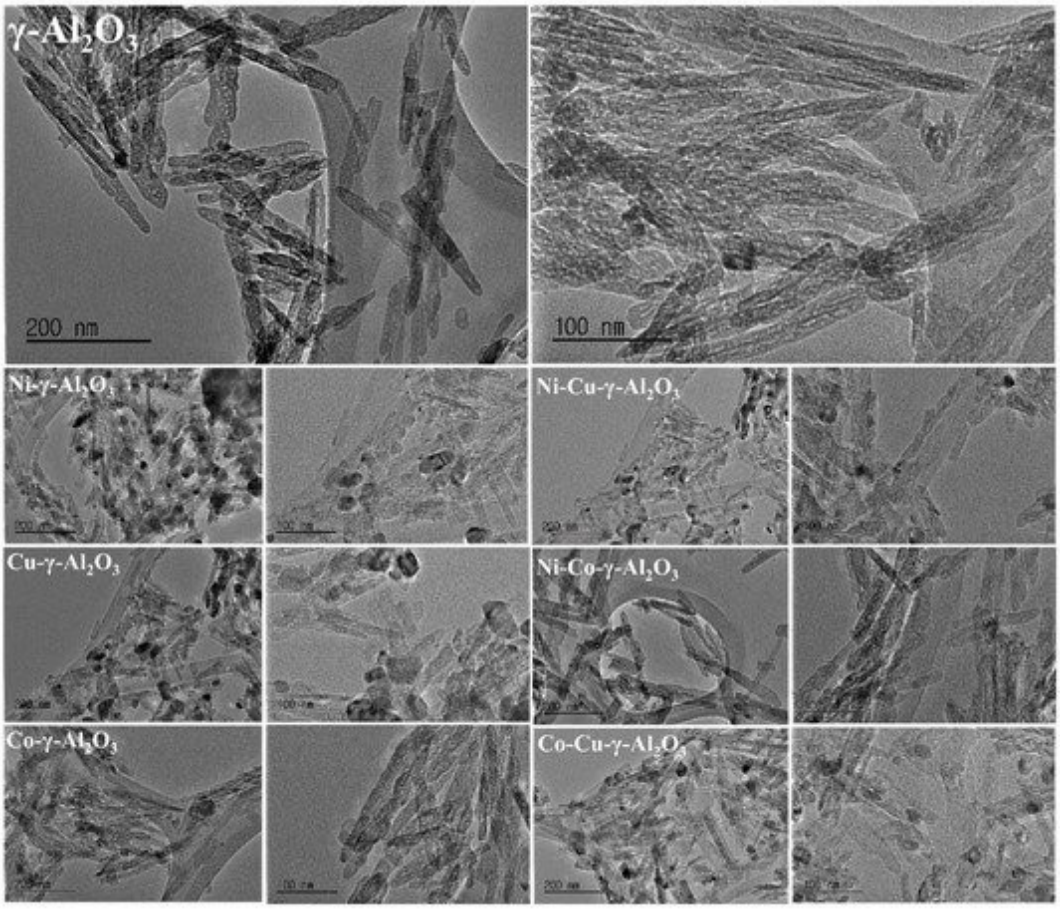

a)
3 μm
b)
300 nm
c)
Al
Co
Ni

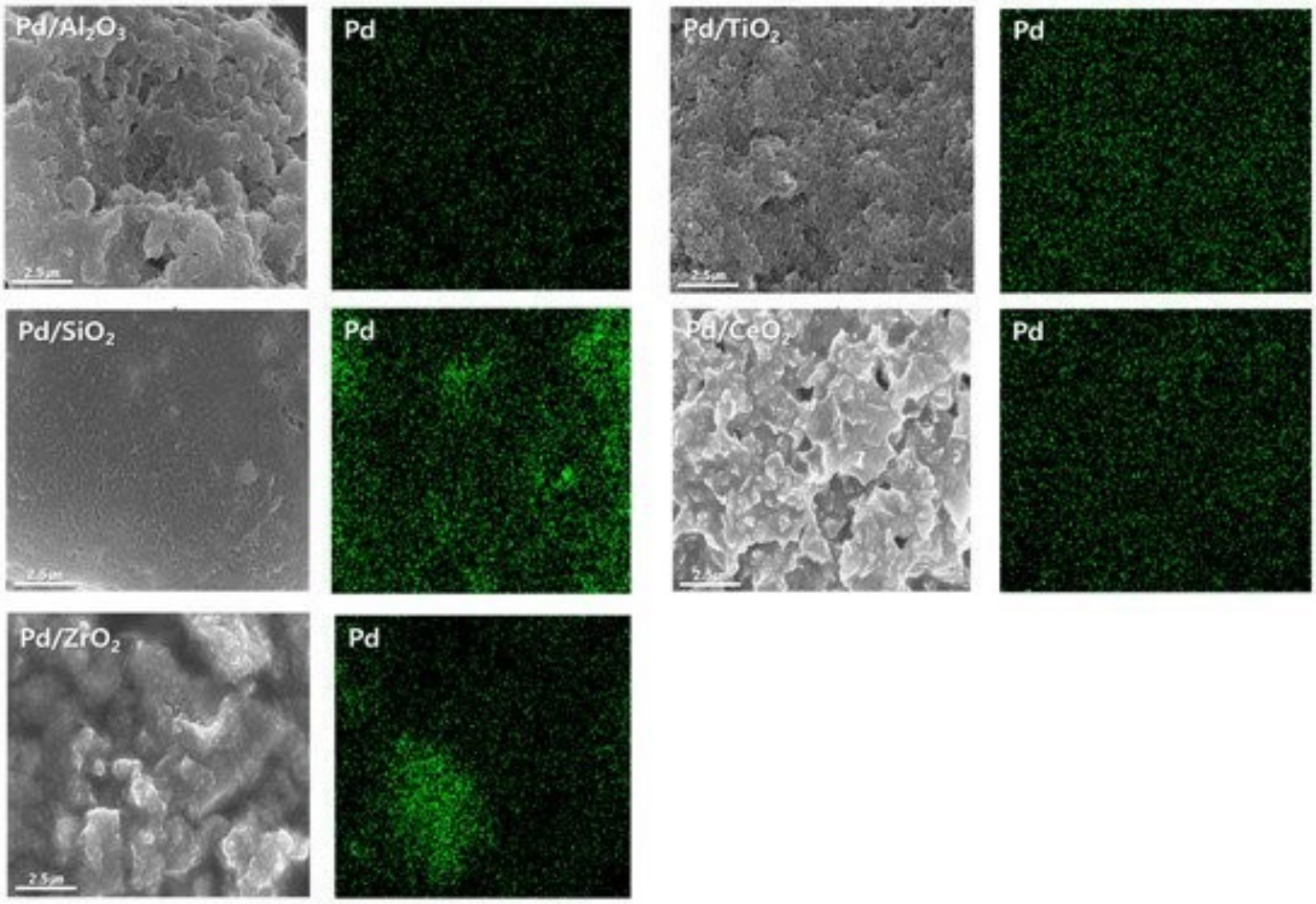

a)
3 μm
b)
300 nm
c)
Al
Co
Ni
Pt

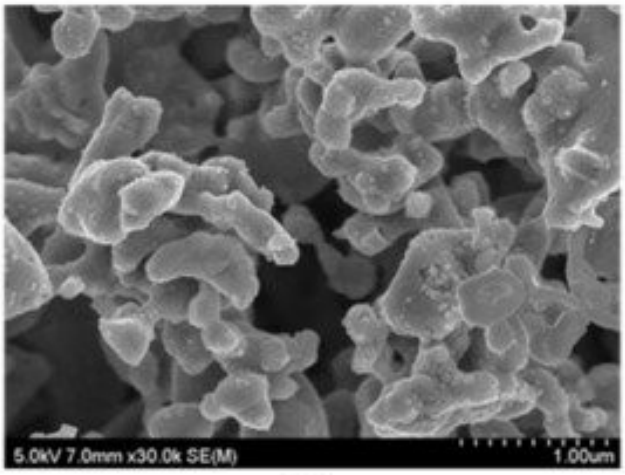

(a)
Al2O3 overcoat
20 nm
(b)
20 nm
Al
20 nm
O
20 nm
Pd
20 nm
Si
20 nm
20 nm
(c)
Al2O3 overcoat
20 nm
(d)
20 nm
Al
20 nm
O
20 nm
Pd
20 nm
Si
20 nm
20 nm


a)
Soot conversion (%)
100
80
60
40
20
0
T 90
T 50
T 10
300 350 400 450 500 550 600
Temperature (°C)
① No catalyst
② CoAl2O4 - fresh
③ CoAl2O4 - 500 °C
④ CoAl2O4 - 750 °C

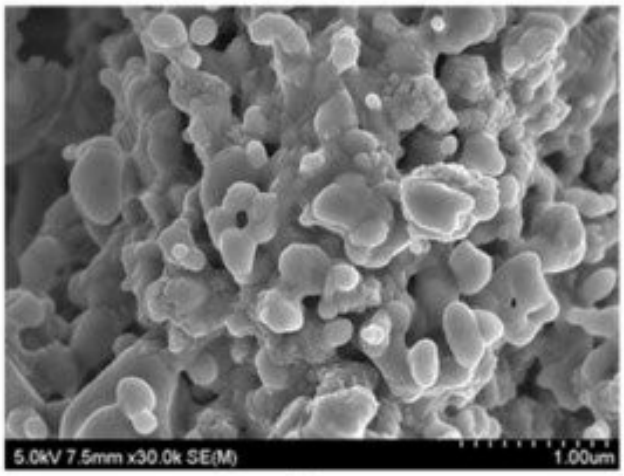

b) CoAl2O4 - fresh
c) CoAl2O4 - 500 °C
d) CoAl2O4 - 750 °C
300 nm
300 nm
300 nm


γ-Al2O3
200 nm
100 nm
Ni-γ-Al2O3
Ni-Cu-γ-Al2O3
Cu-γ-Al2O3
Ni-Co-γ-Al2O3
Co-γ-Al2O3
Co-Cu-γ-Al2O3

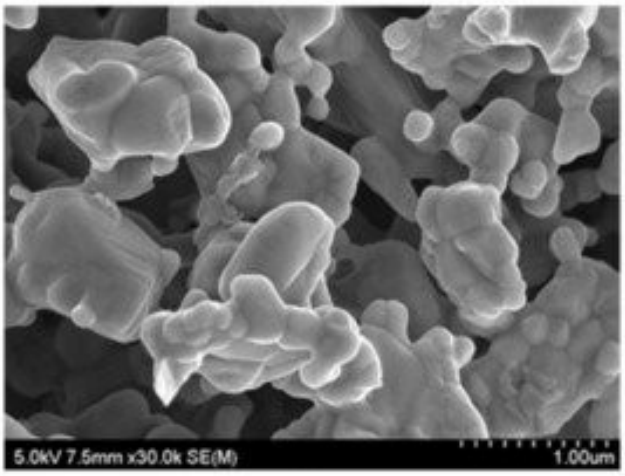

Pd/Al2O3
Pd
Pd/TiO2
Pd
Pd/SiO2
Pd
Pd/CeO2
Pd
Pd/ZrO2
Pd


5.0kV 7.0mm x30.0k SE(M)
1.00um

(a)

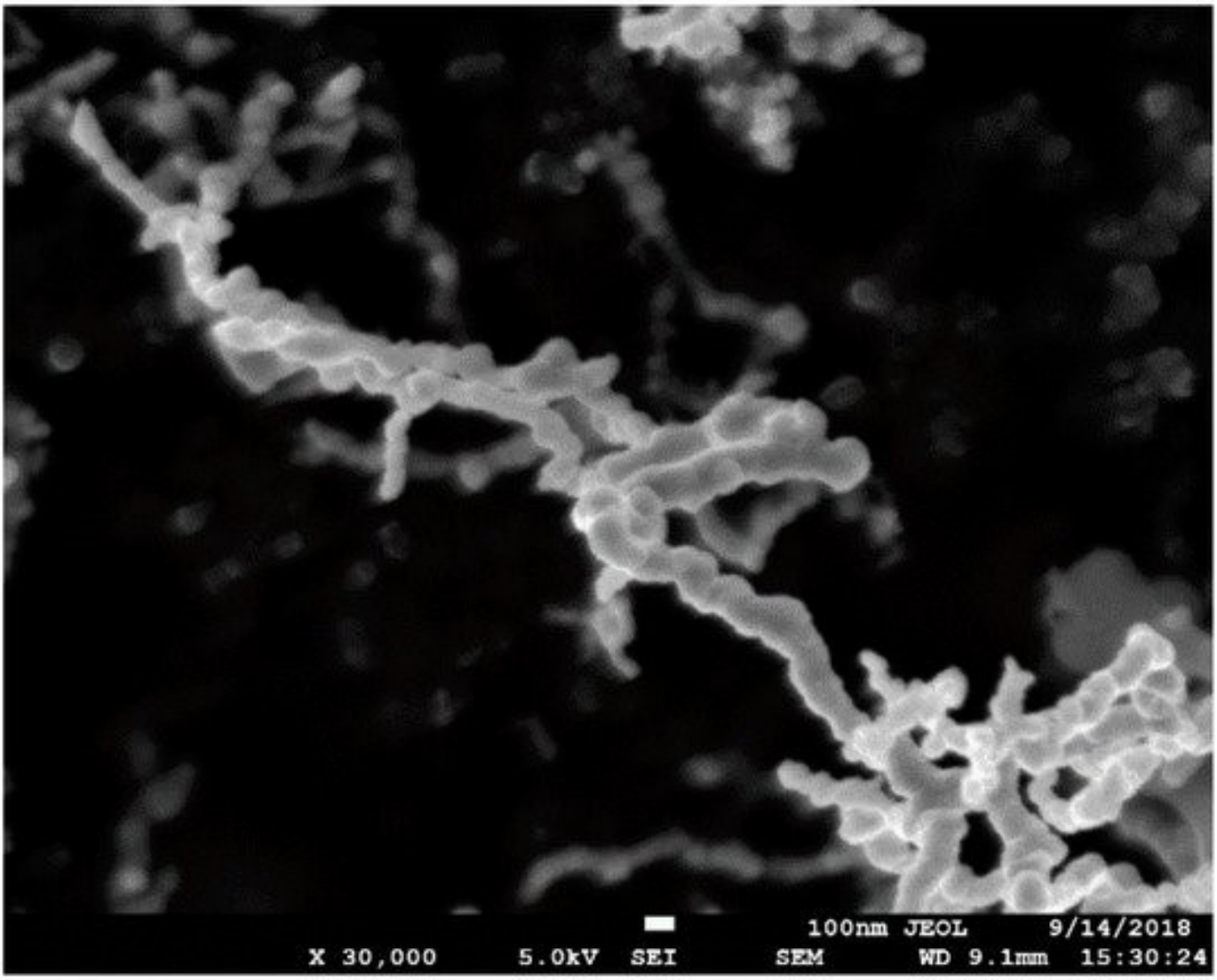

5.0kV 7.5mm x30.0k SE(M)
1.00um

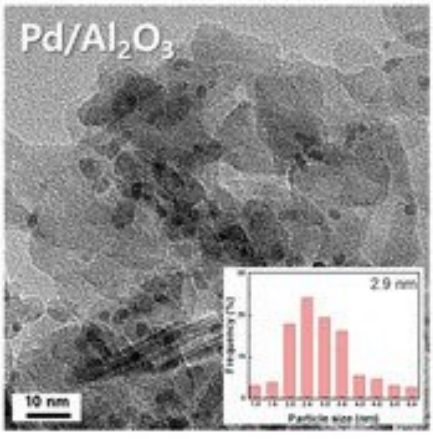
(b)

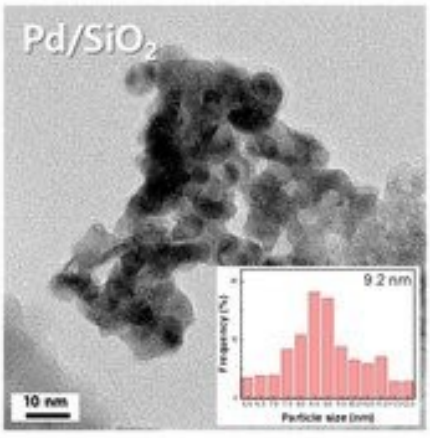

5.0kV 7.5mm x30.0k SE(M)
1.00um

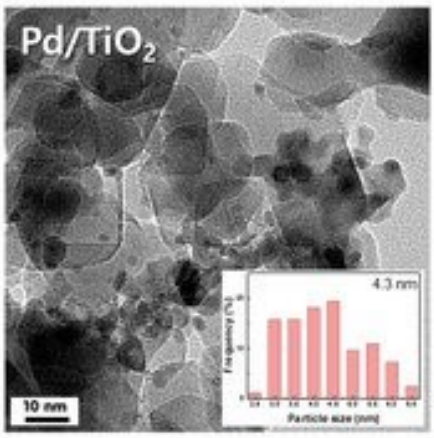
(c)

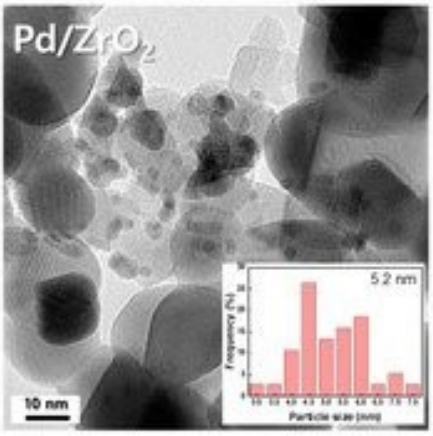
A1]

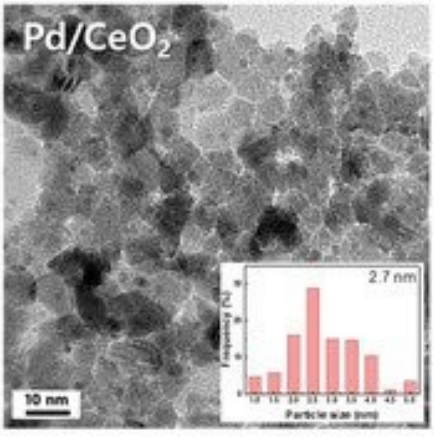

X 30,000 5.0kV SEI SEM WD 9.1mm 15:30:24
100nm JEOL 9/14/2018

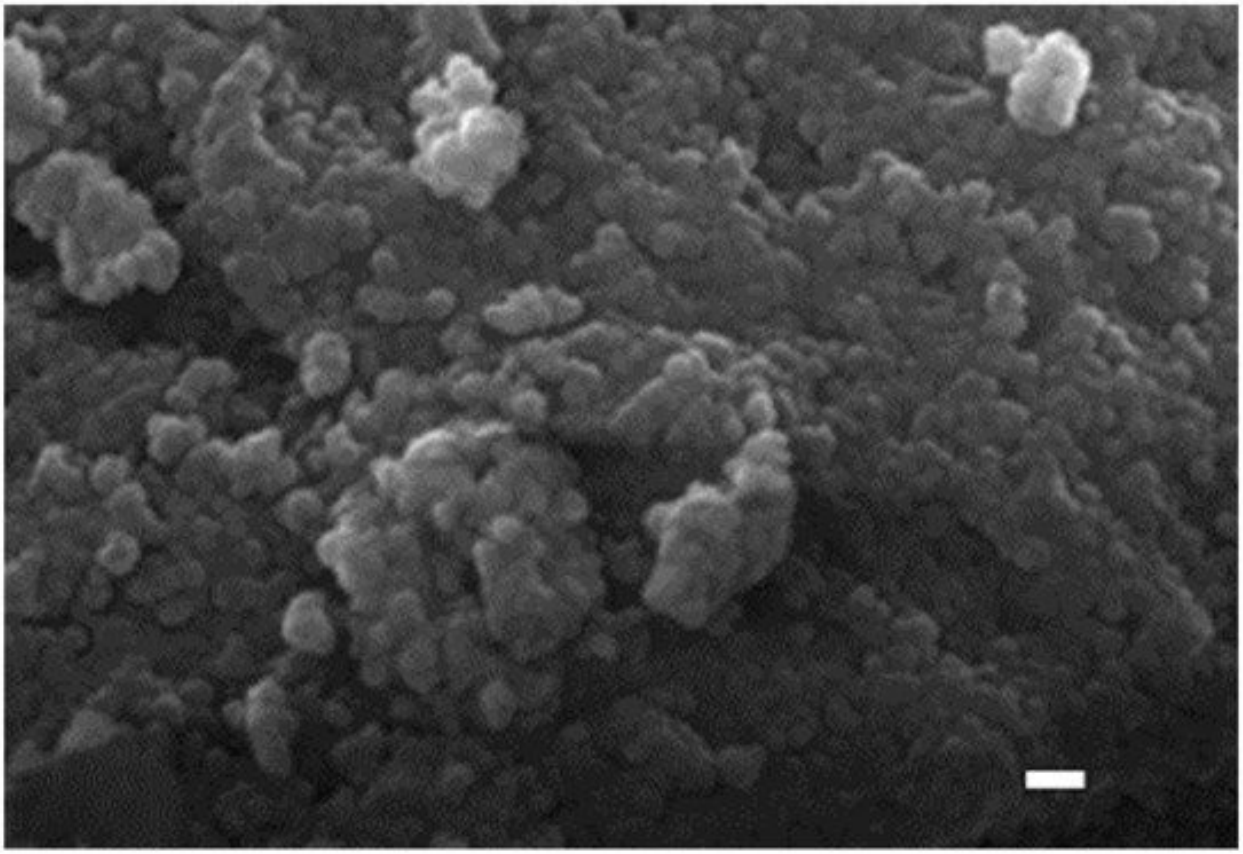

Pd/Al2O3
2.9 nm
10 nm
Particle size (nm)

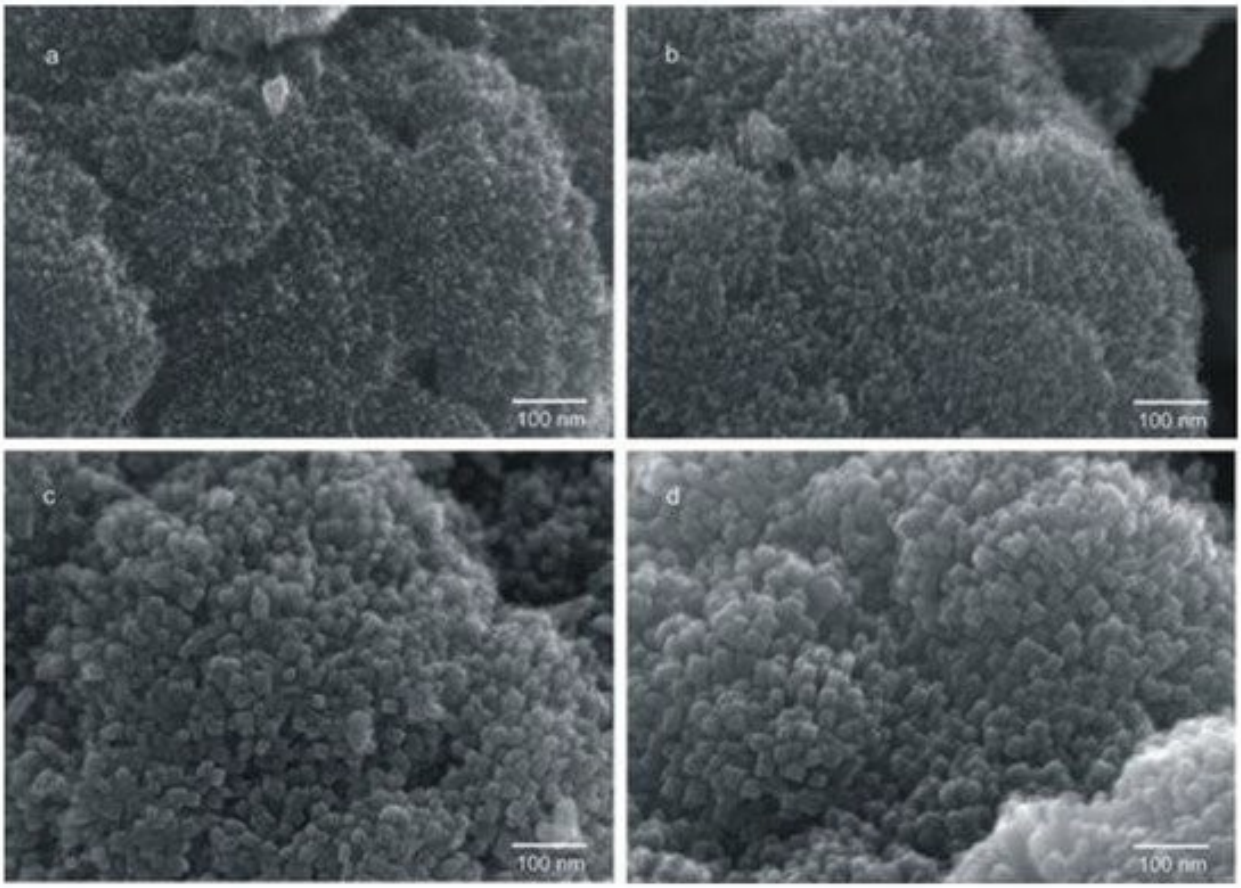

Pd/SiO2
9.2 nm
10 nm
Particle size (nm)

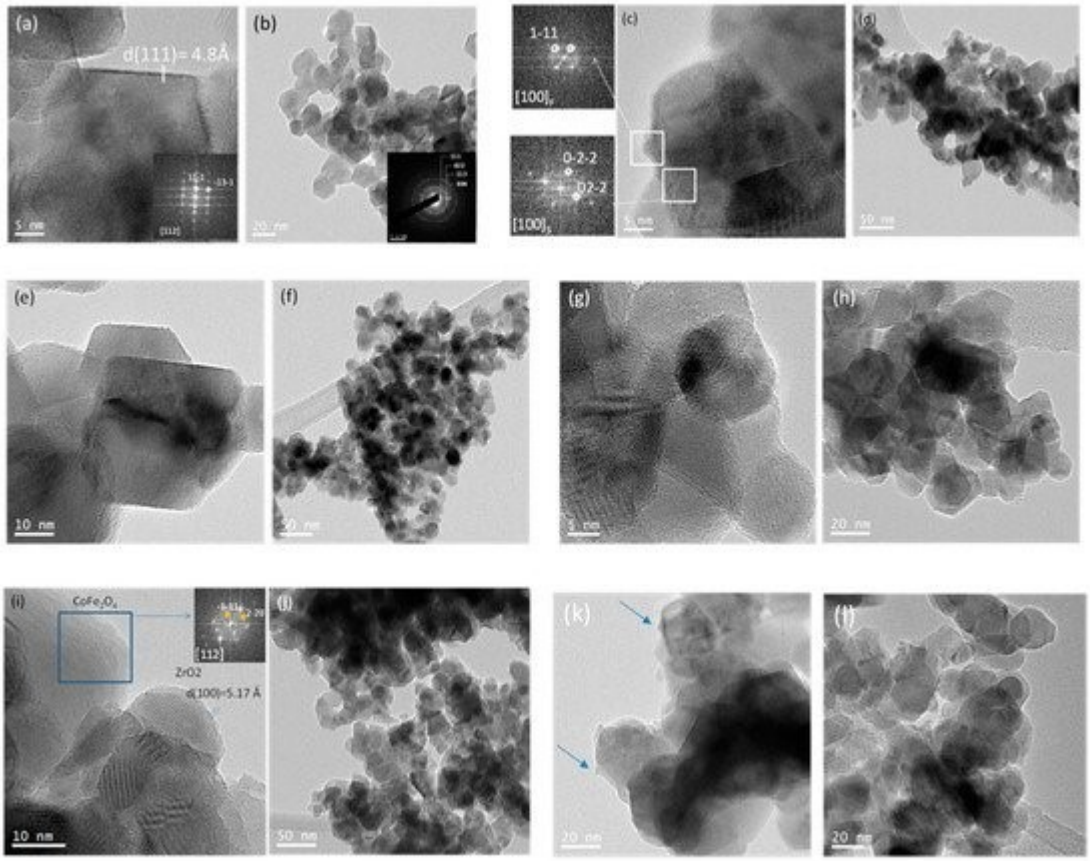

Pd/TiO2
4.3 nm
10 nm
Particle size (nm)

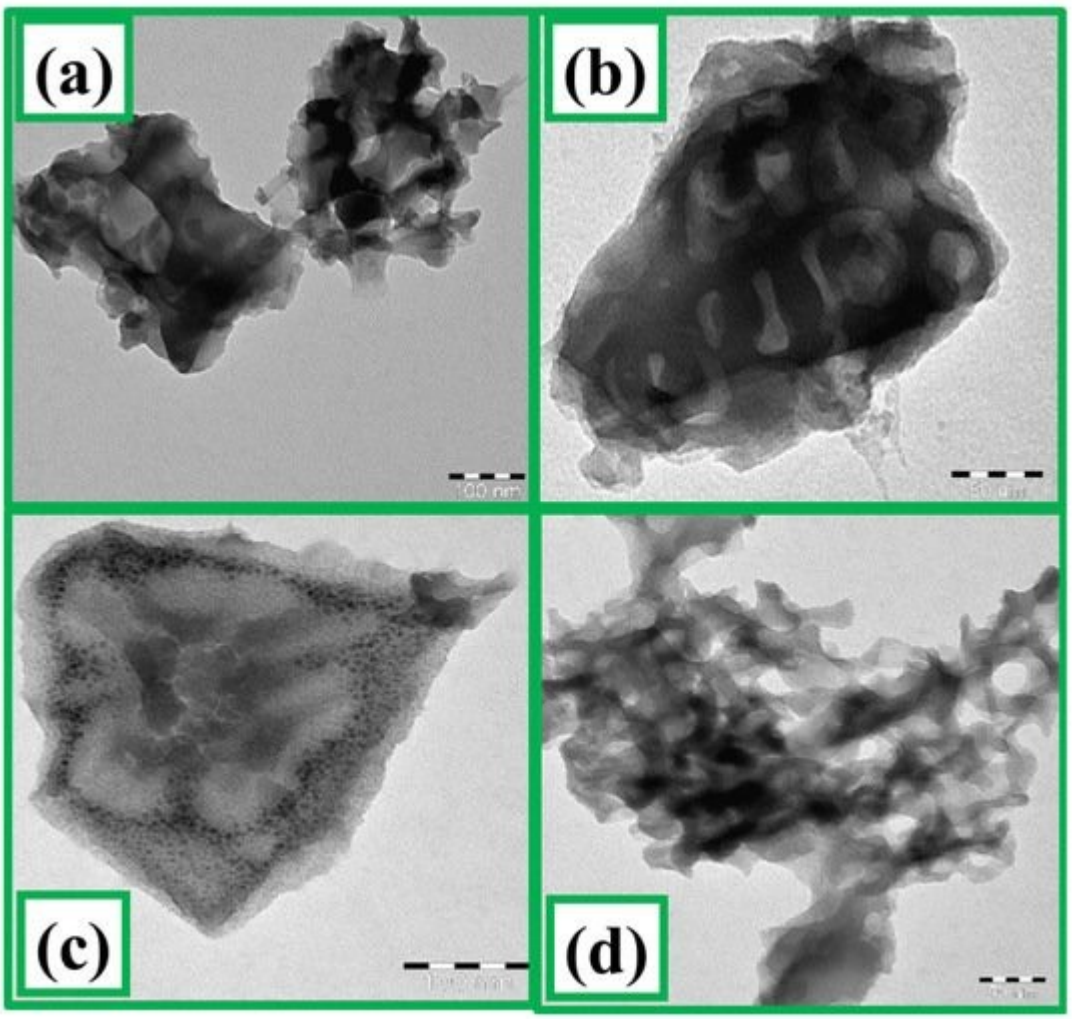

Pd/ZrO2
5.2 nm
10 nm
Particle size (nm)

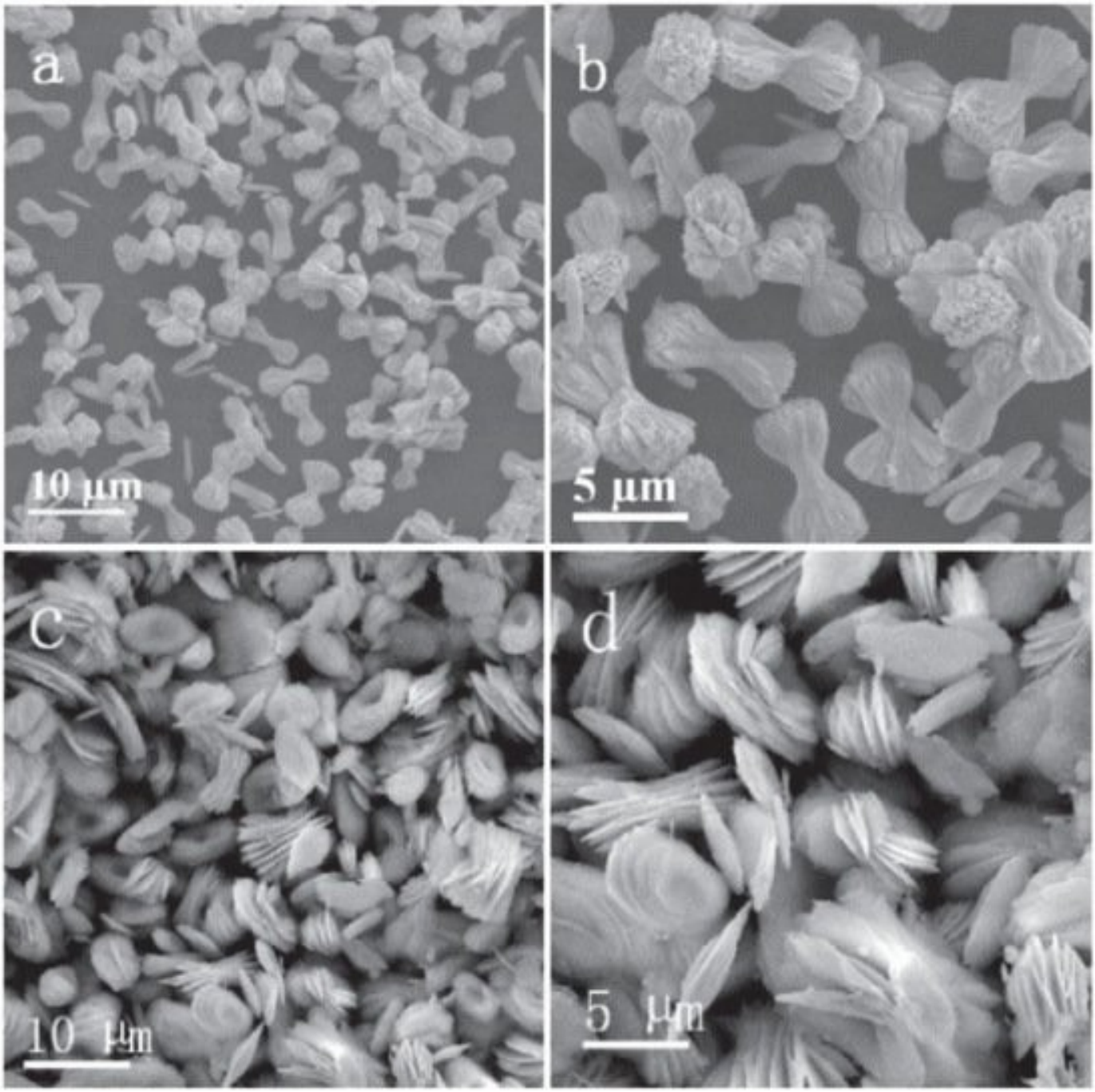

Pd/CeO2
2.7 nm
10 nm
Particle size (nm)

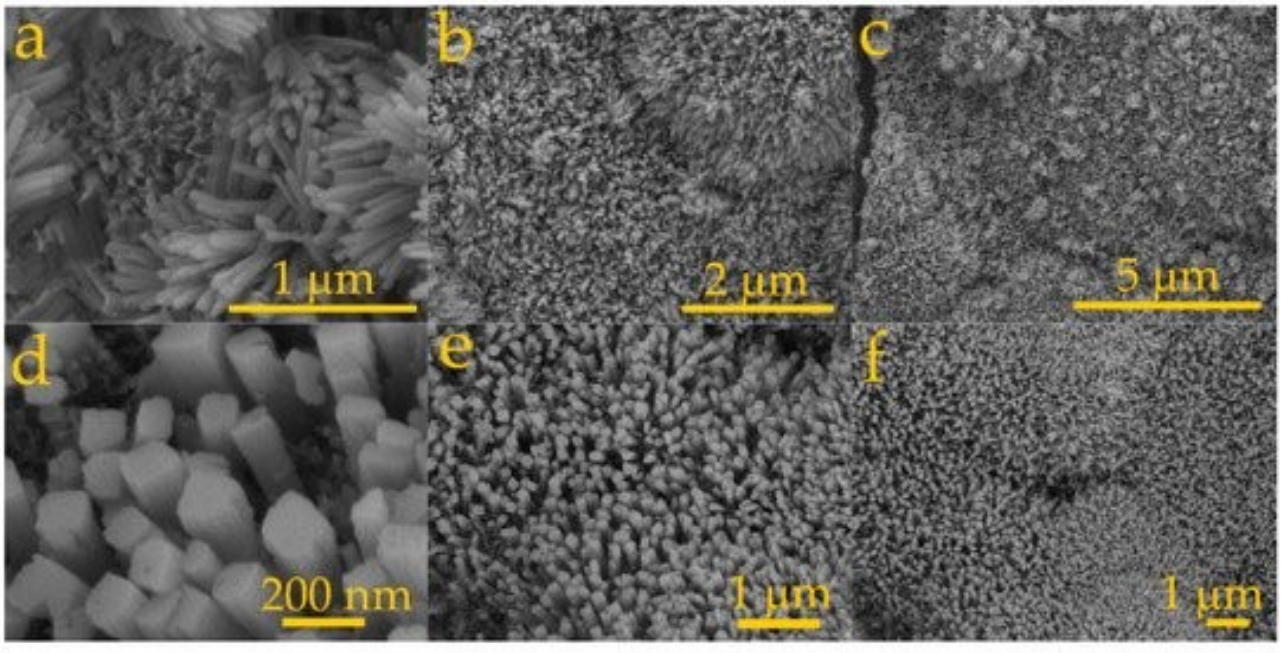


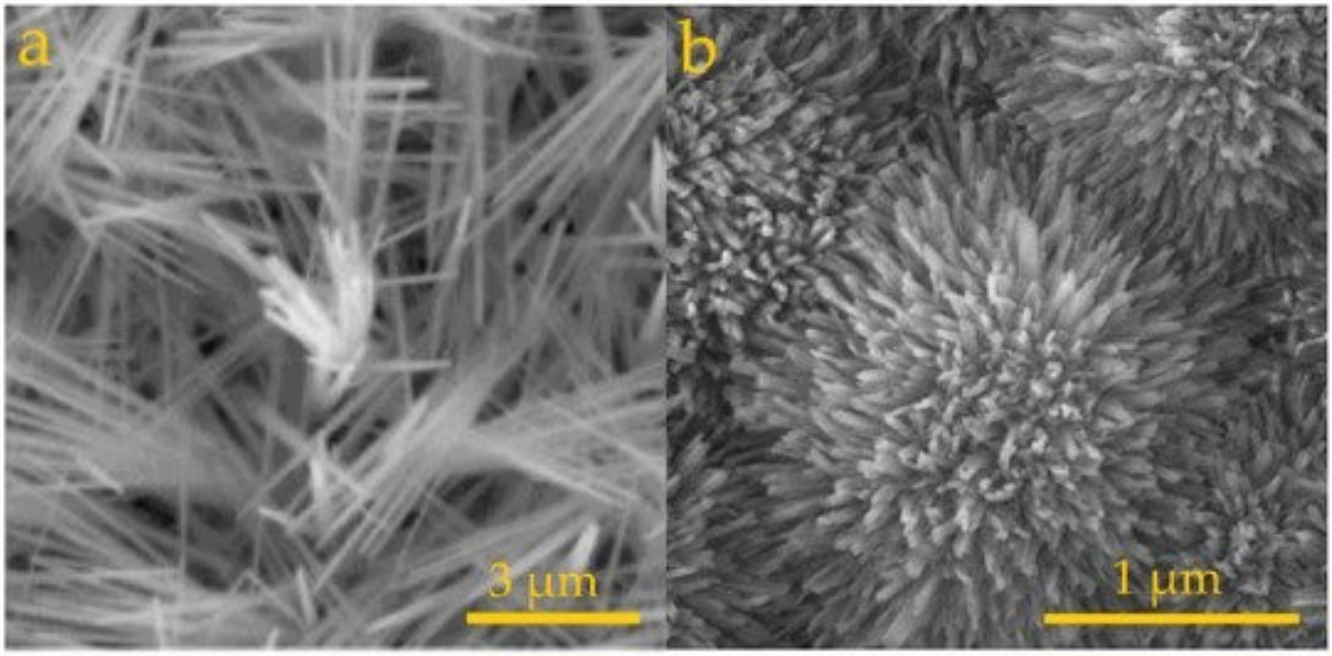

a
100 nm
b
100 nm
c
100 nm
d
100 nm

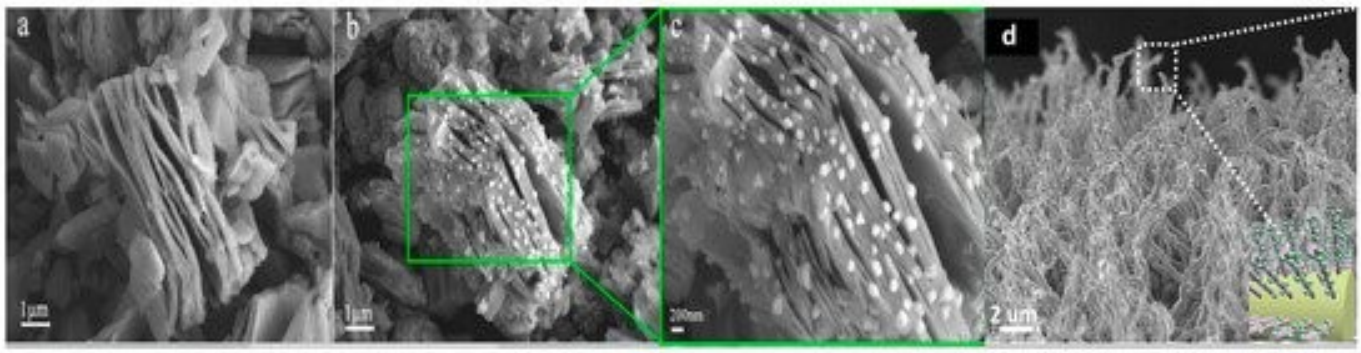

(a)
d(111)= 4.8Å
(b)
(c)
1-11
[100]z
0-2-2
02-2
[100]z
(d)
(e)
(f)
(g)
(h)
(i)
CoFe2O4
[112]
ZrO2
d(100)=5.17 Å
(j)
(k)
(l)

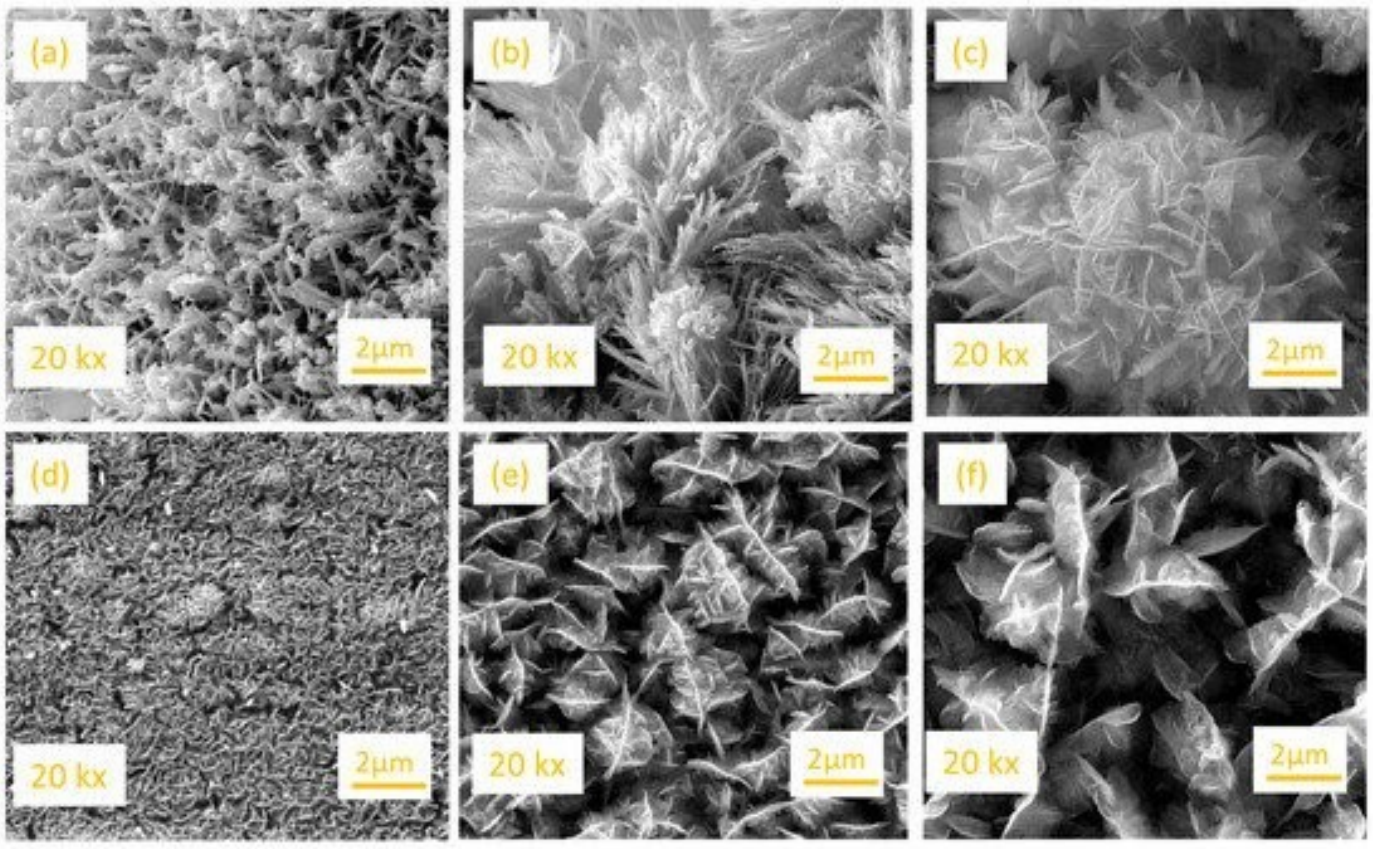

(a)
(b)
(c)
(d)

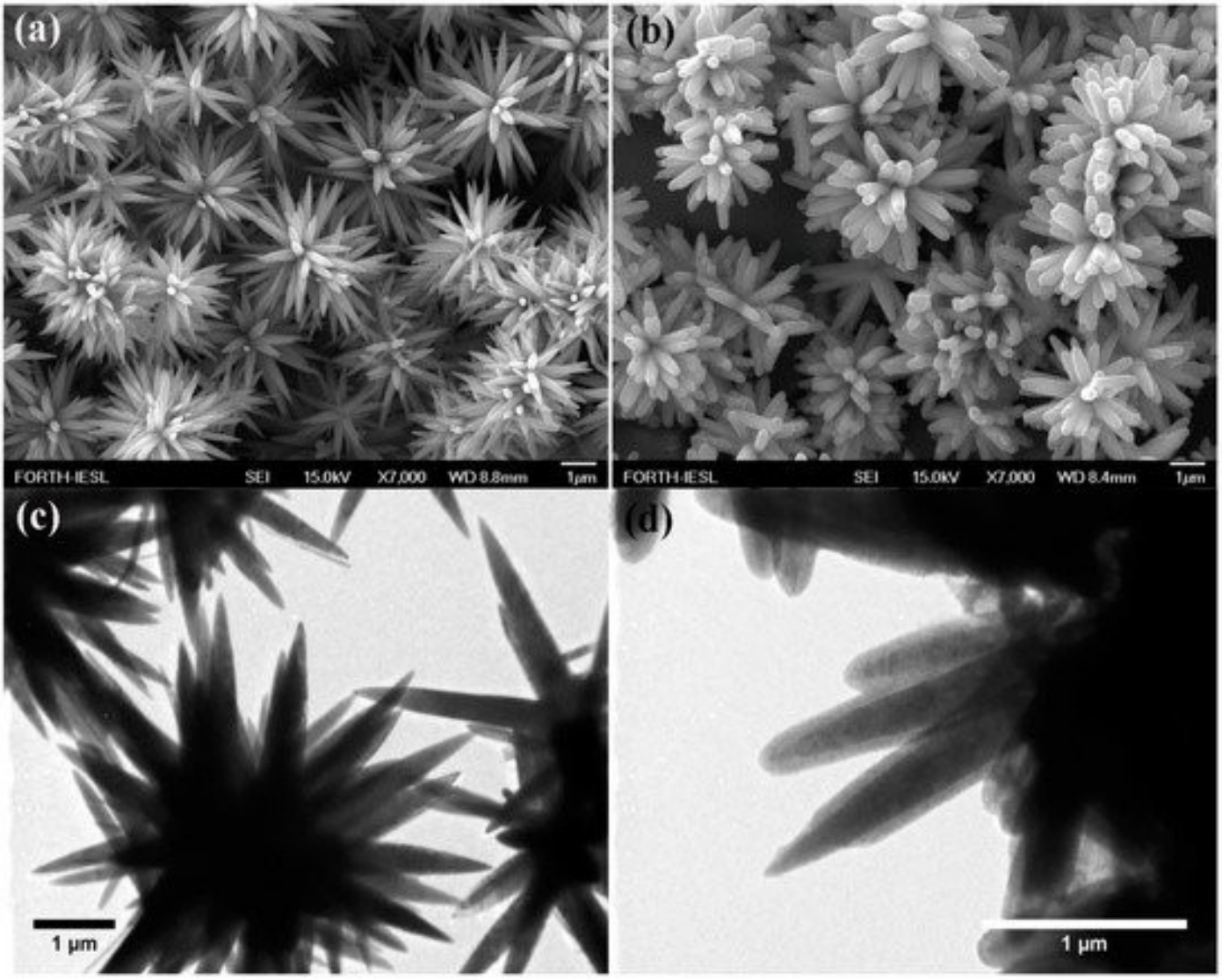

a
10 μm
b
5 μm
c
10 μm
d
5 μm

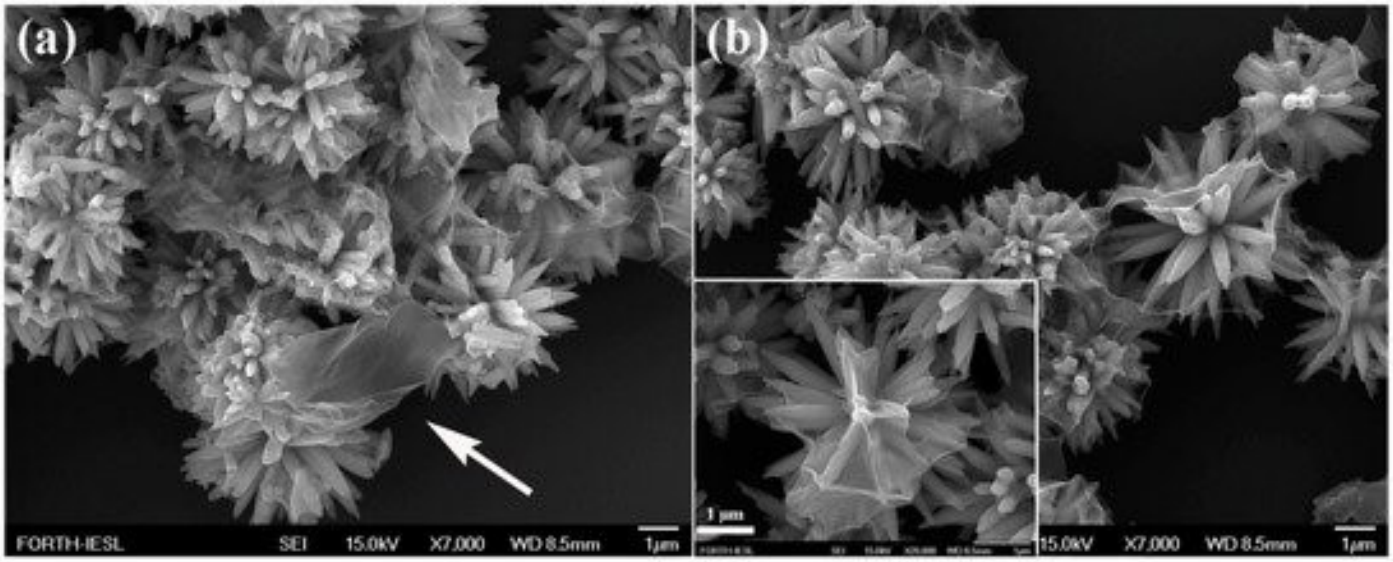

a
1 μm
b
2 μm
c
5 μm
d
200 nm
e
1 μm
f
1 μm

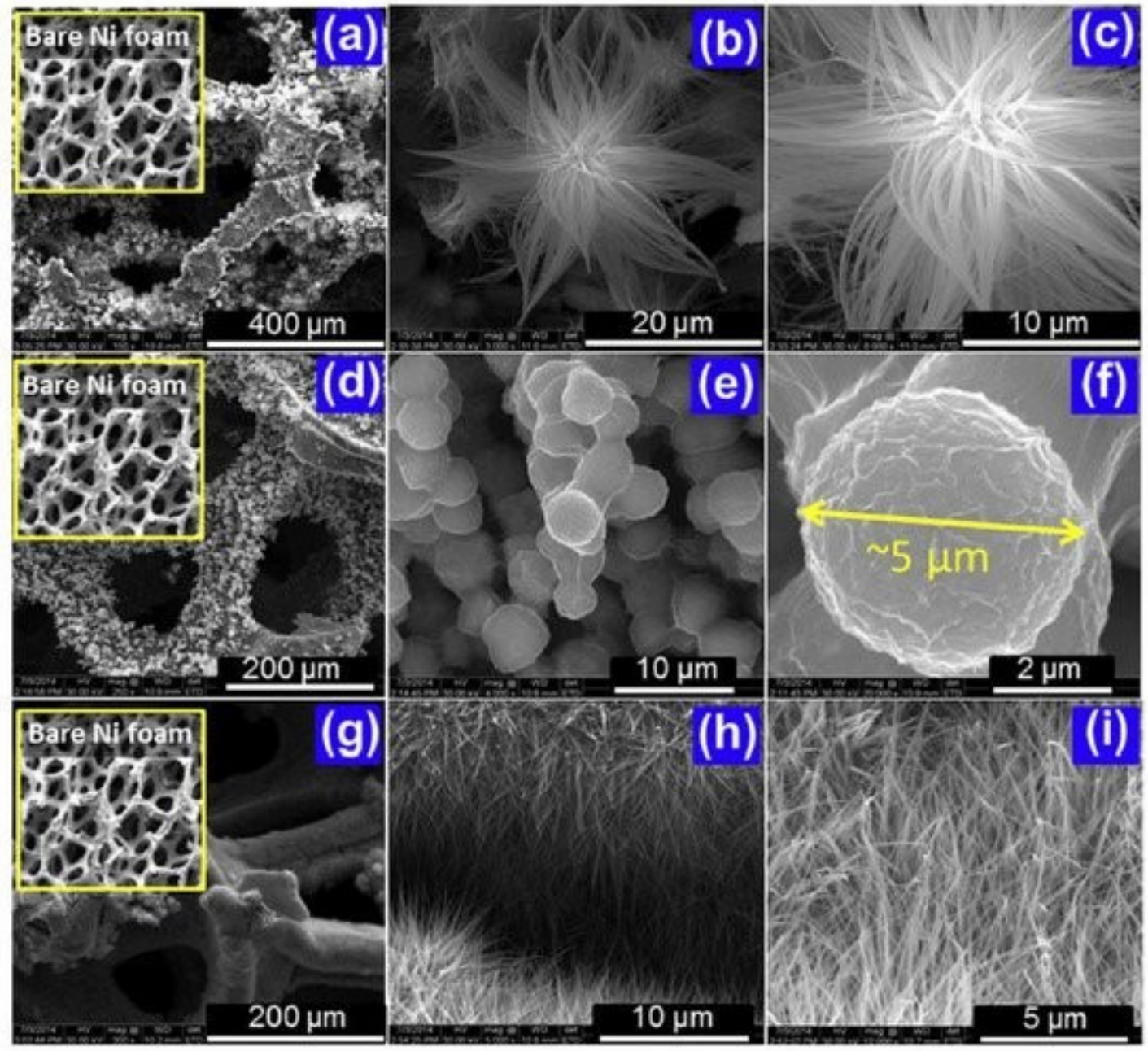

a
3 µm
b
1 µm

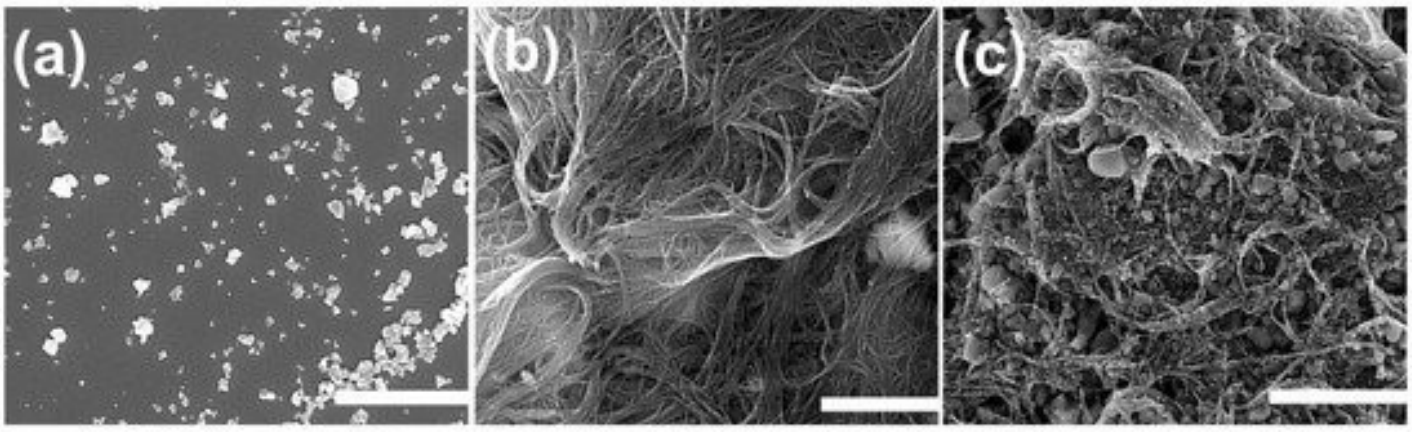

a
1µm
b
1µm
c
d
2 µm

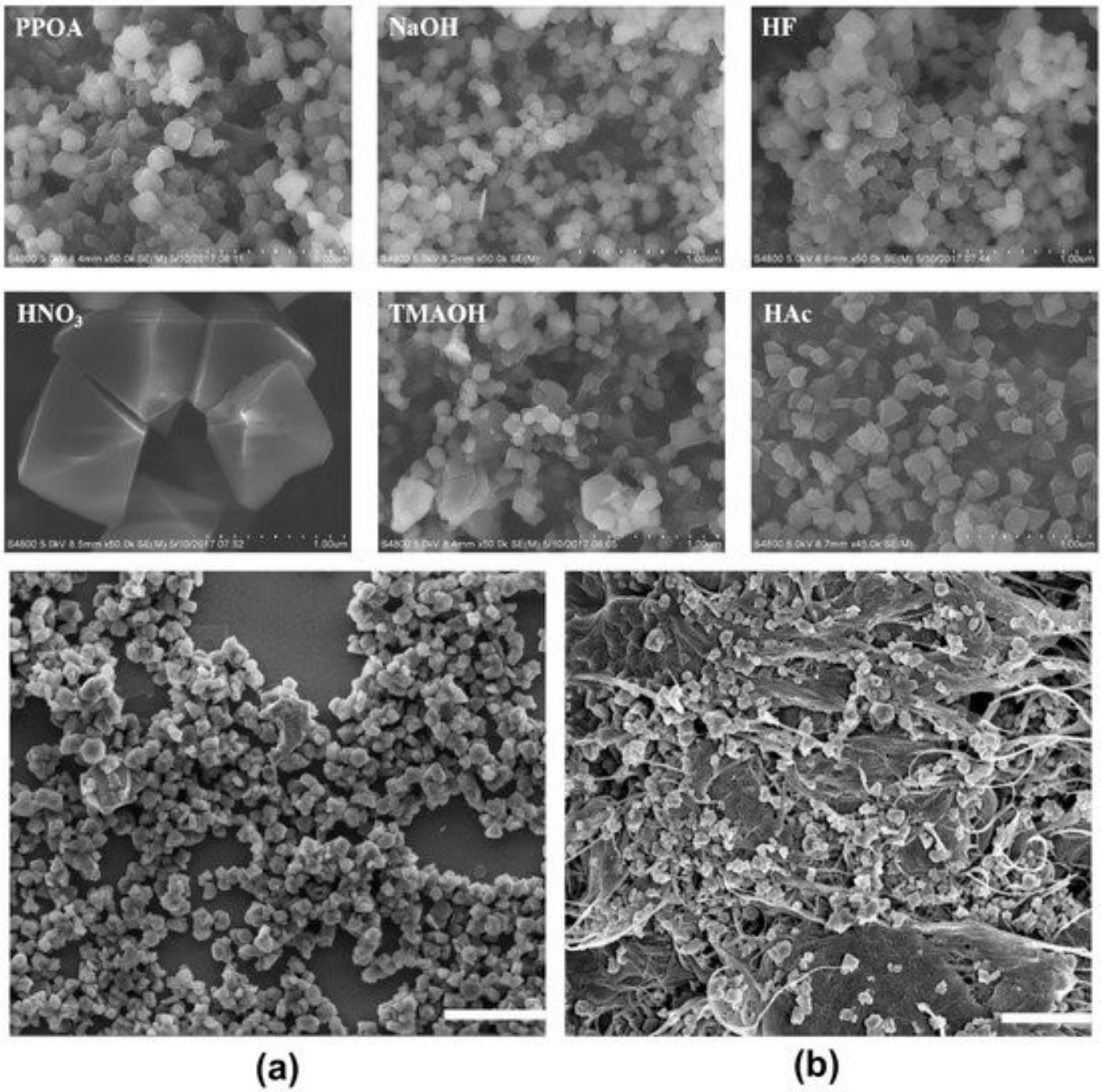

(a)
20 kx
2µm
(b)
20 kx
2µm
(c)
20 kx
2µm
(d)
20 kx
2µm
(e)
20 kx
2µm
(f)
20 kx
2µm

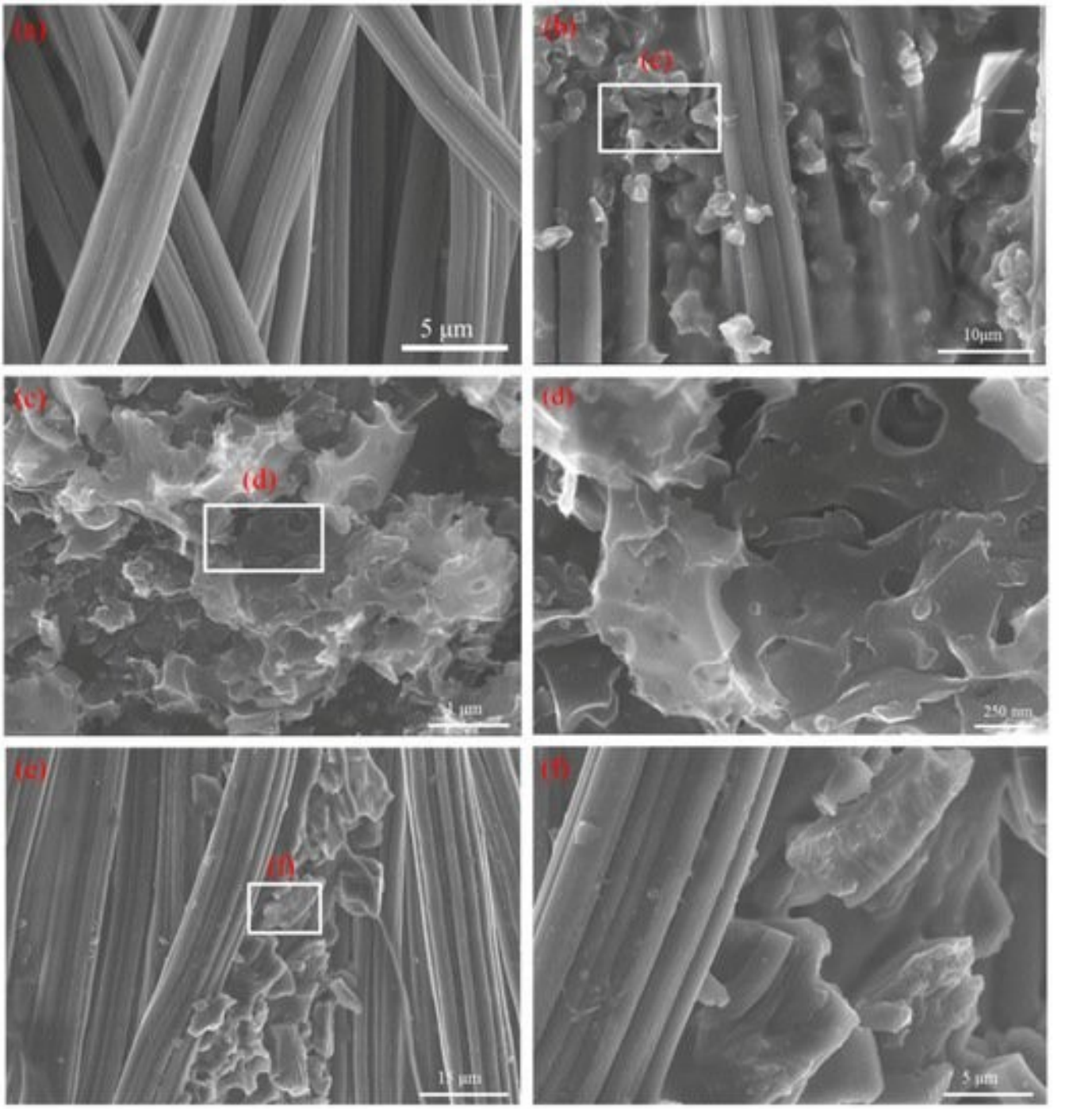

(a)
FORTH-IESL SEI 15.0kV X7,000 WD 8.8mm 1μm
(b)
FORTH-IESL SEI 15.0kV X7,000 WD 8.4mm 1μm
(c)
1 μm
(d)
1 μm

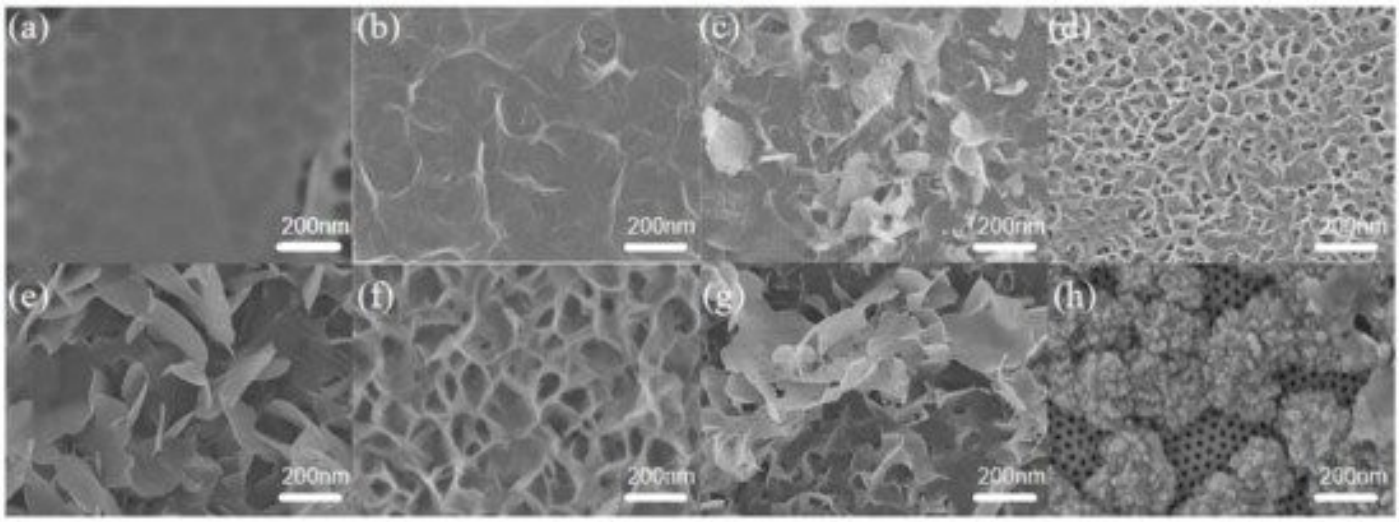

(a)
FORTH-IESL SEI 15.0kV X7,000 WD 8.5mm 1μm
(b)
1 μm
15.0kV X7,000 WD 8.5mm 1μm

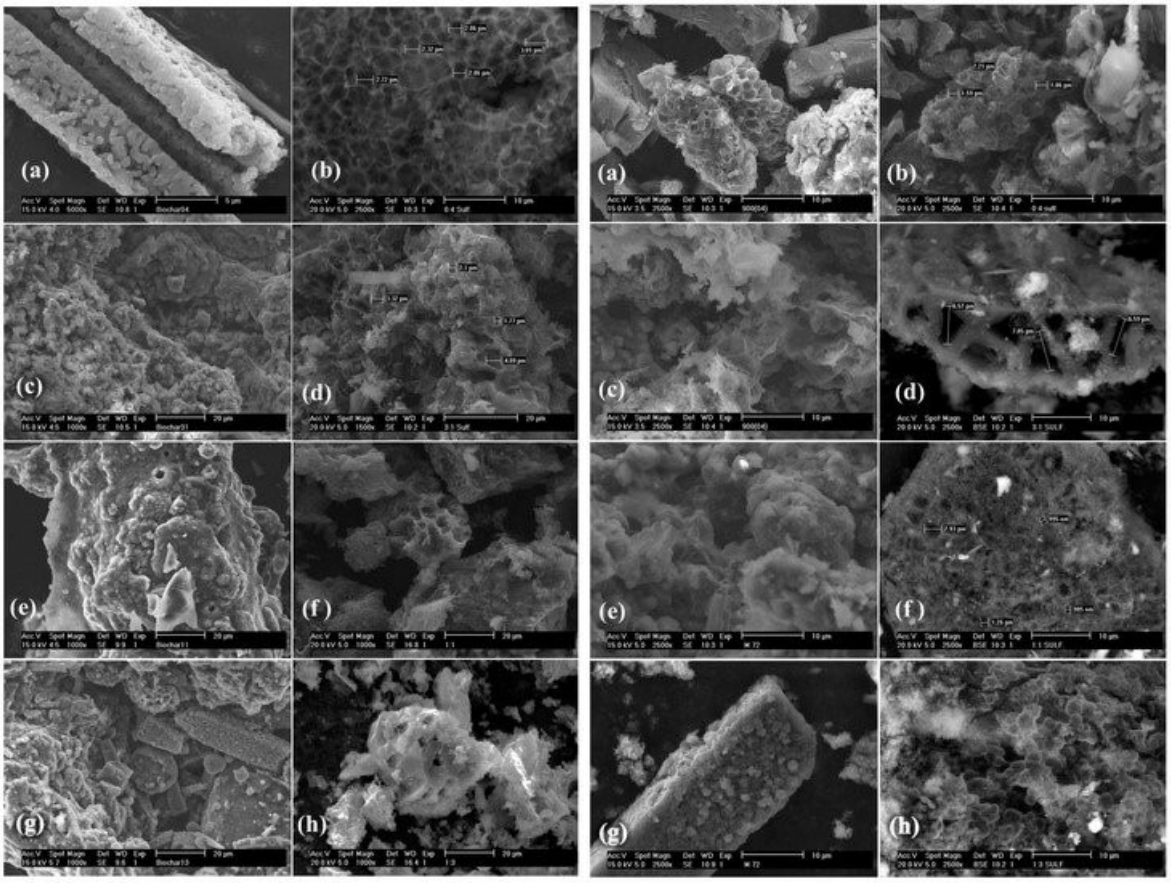

Bare Ni foam
(a)
400 µm
(b)
20 µm
(c)
10 µm
Bare Ni foam
(d)
200 µm
(e)
10 µm
(f)
~5 µm
2 µm
Bare Ni foam
(g)
200 µm
(h)
10 µm
(i)
5 µm

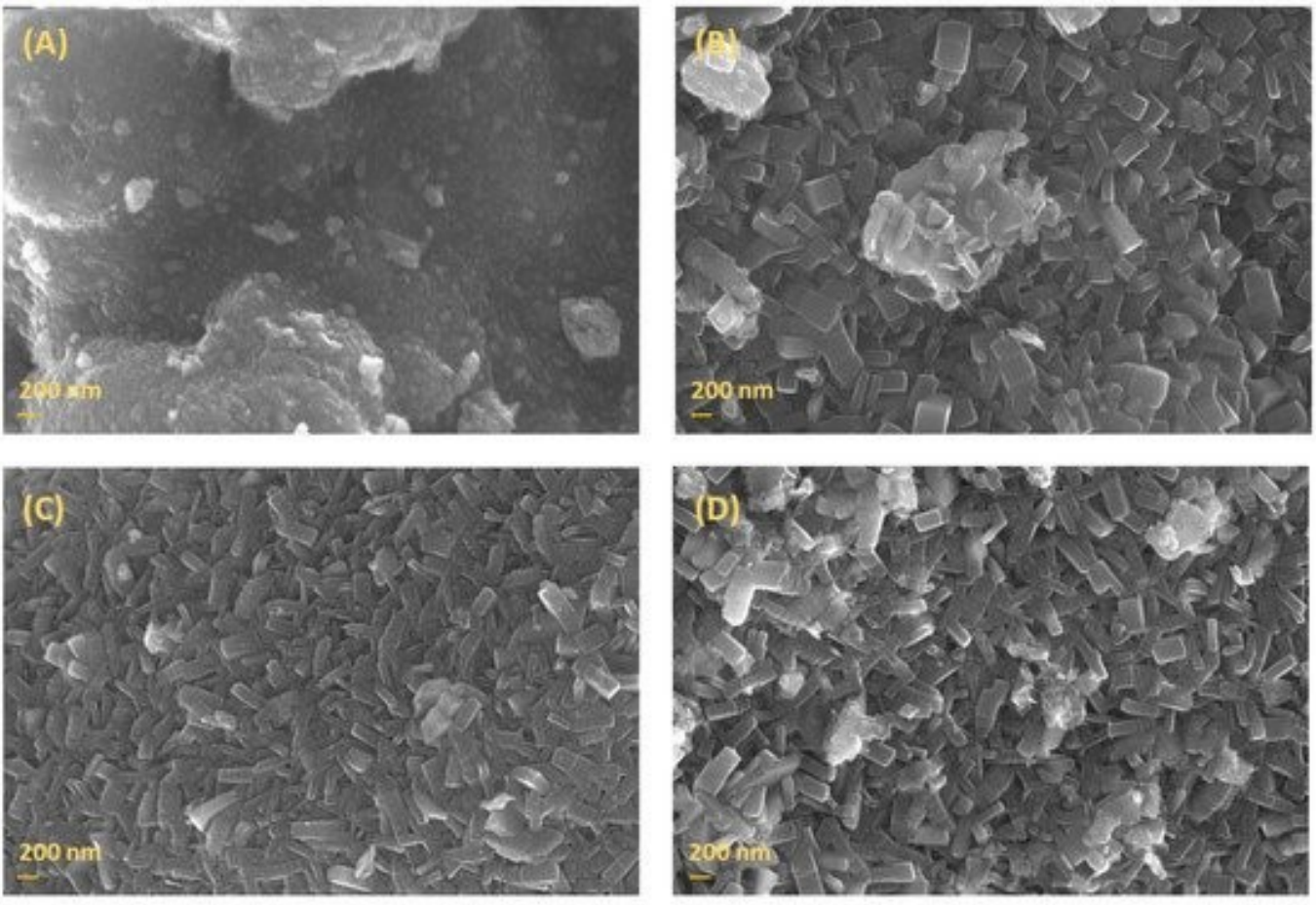

(a)
(b)
(c)

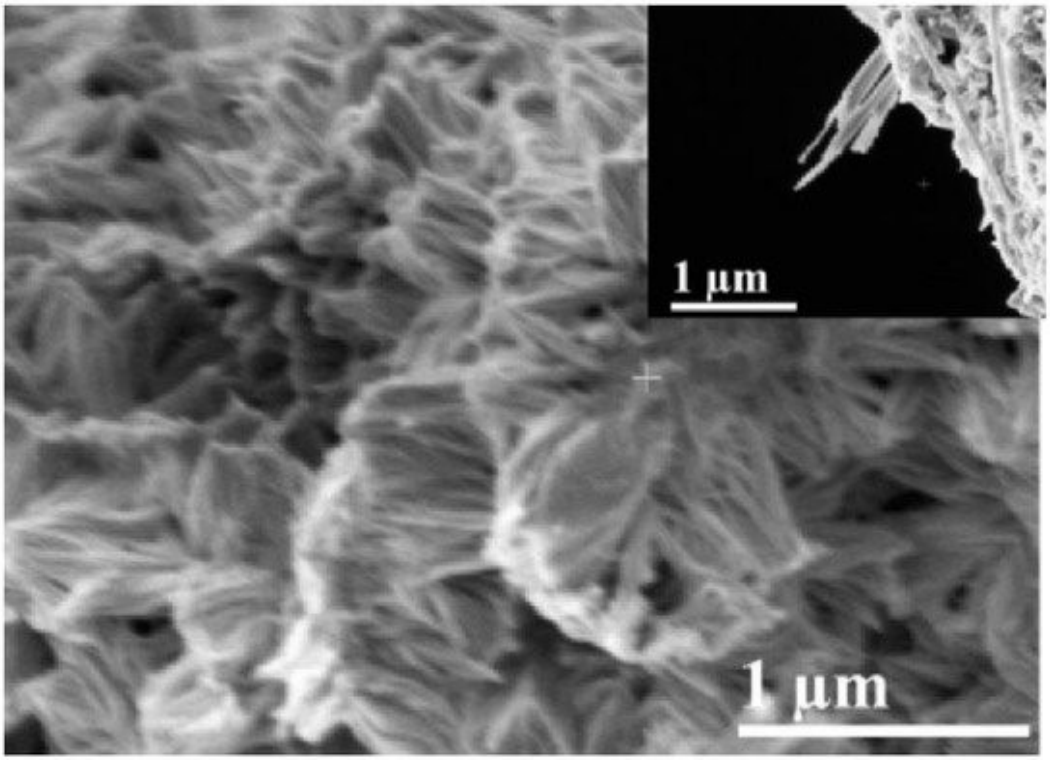

PPOA
NaOH
HF
HNO3
TMAOH
HAc
(a)
(b)

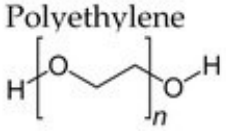

(a)
5 μm
(b)
(c)
10μm
(c)
(d)
(d)
250 nm
(e)
(f)
(f)
5 μm

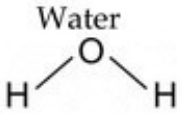

(a)
200nm
(b)
200nm
(c)
200nm
(d)
200nm
(e)
200nm
(f)
200nm
(g)
200nm
(h)
200nm

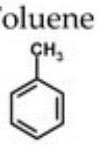

(a)
(b)
(c)
(d)
(e)
(f)
(g)
(h)
(a)
(b)
(c)
(d)
(e)
(f)
(g)
(h)

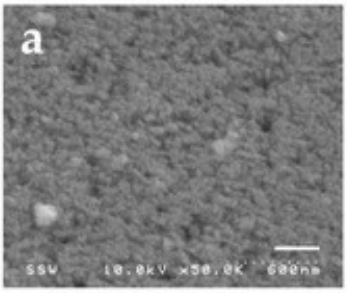

(A)
200 nm
(B)
200 nm
(C)
200 nm
(D)
200 nm

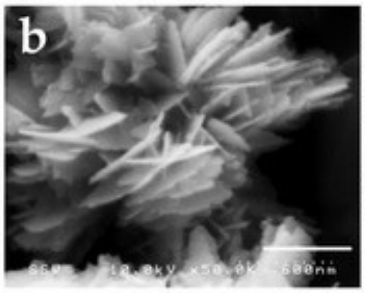

1 μm
1 μm

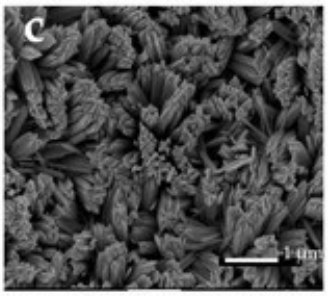

Polyethylene
H
O
O
H
n

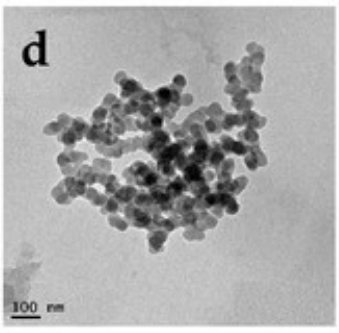

Water
O
H
H

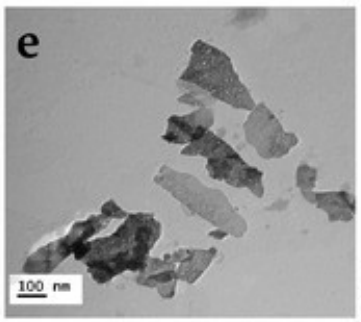

Toluene
CH3

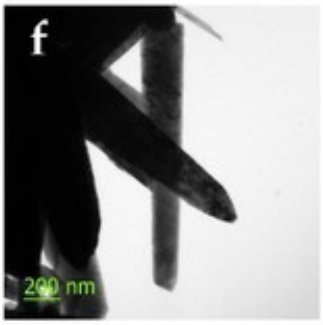

a

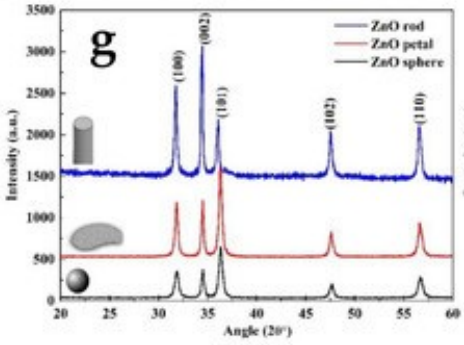

b

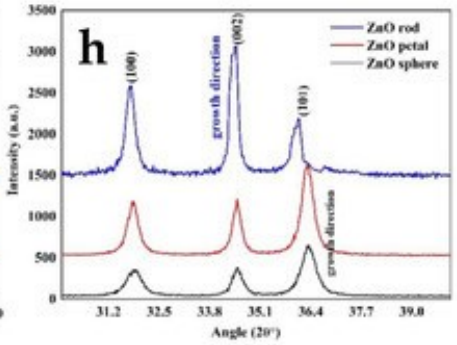

c

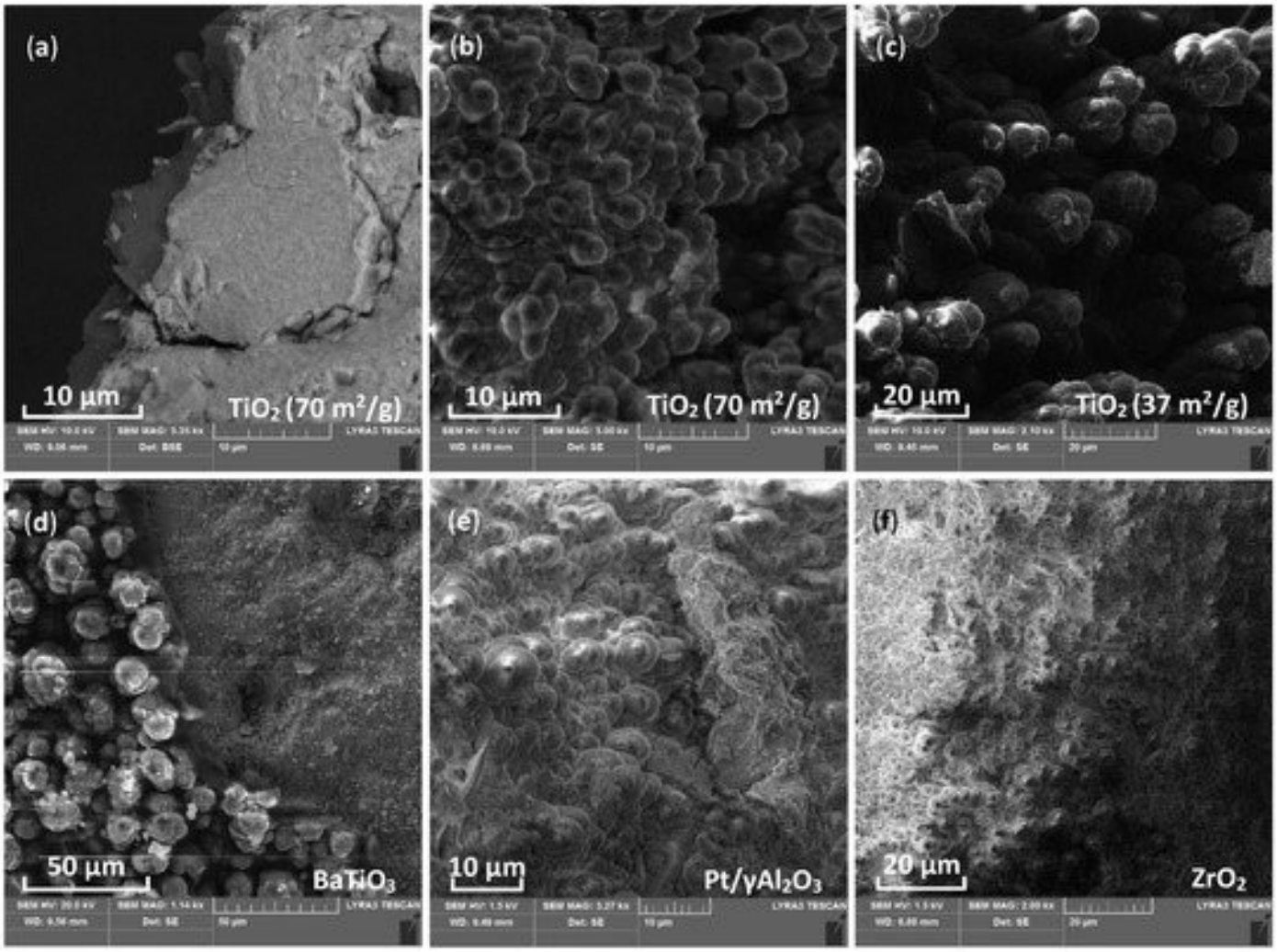

d
100 nm

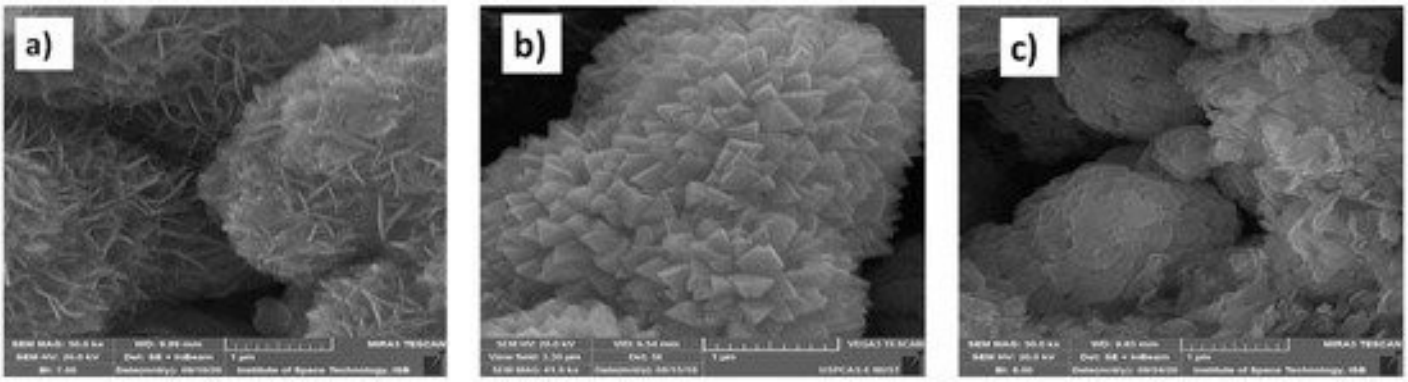

e
100 nm

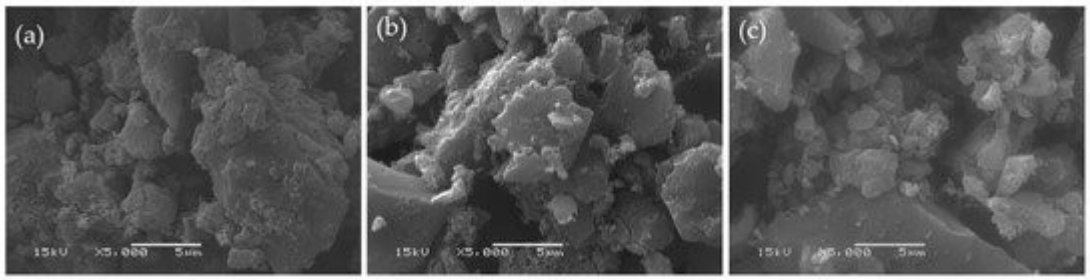

f
200 nm

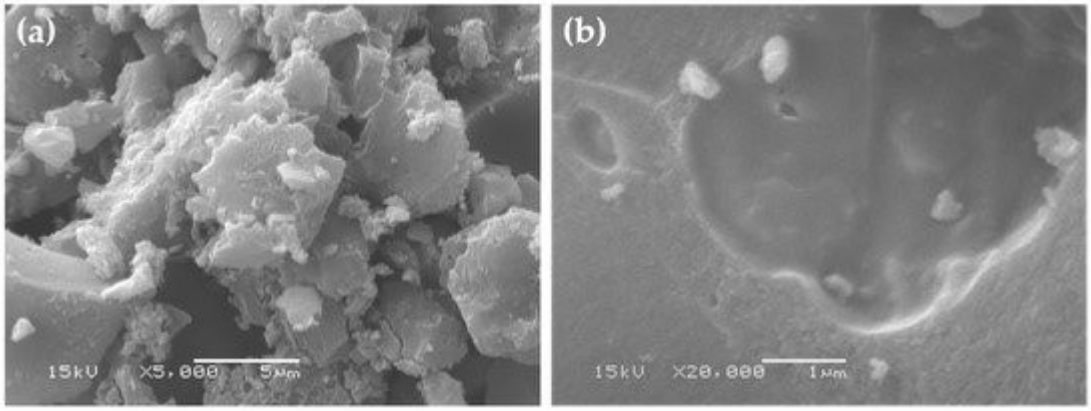

g
ZnO rod
ZnO petal
ZnO sphere
(100)
(002)
(101)
(102)
(110)
Intensity (a.u.)
Angle (2θ°)

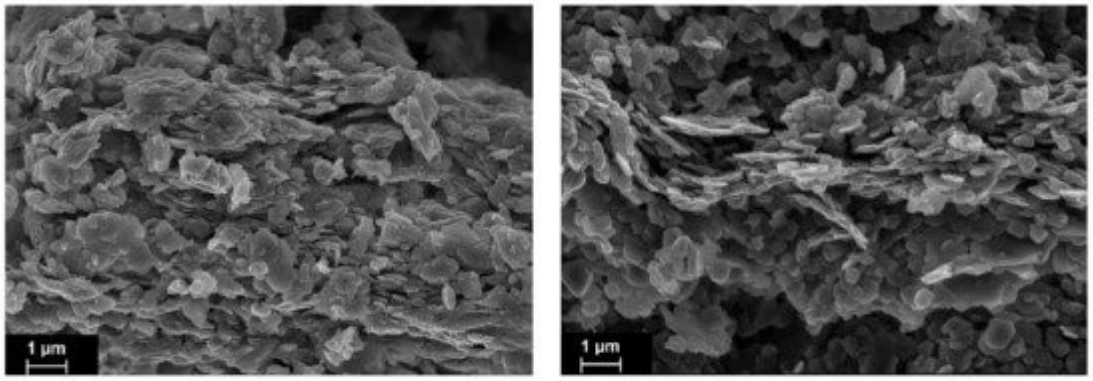

h
ZnO rod
ZnO petal
ZnO sphere
(100)
growth direction
(002)
(101)
Intensity (a.u.)
Angle (2θ°)


(a)
10 µm
TiO2 (70 m2/g)
(b)
10 µm
TiO2 (70 m2/g)
(c)
20 µm
TiO2 (37 m2/g)
(d)
50 µm
BaTiO3
(e)
10 µm
Pt/γAl2O3
(f)
20 µm
ZrO2

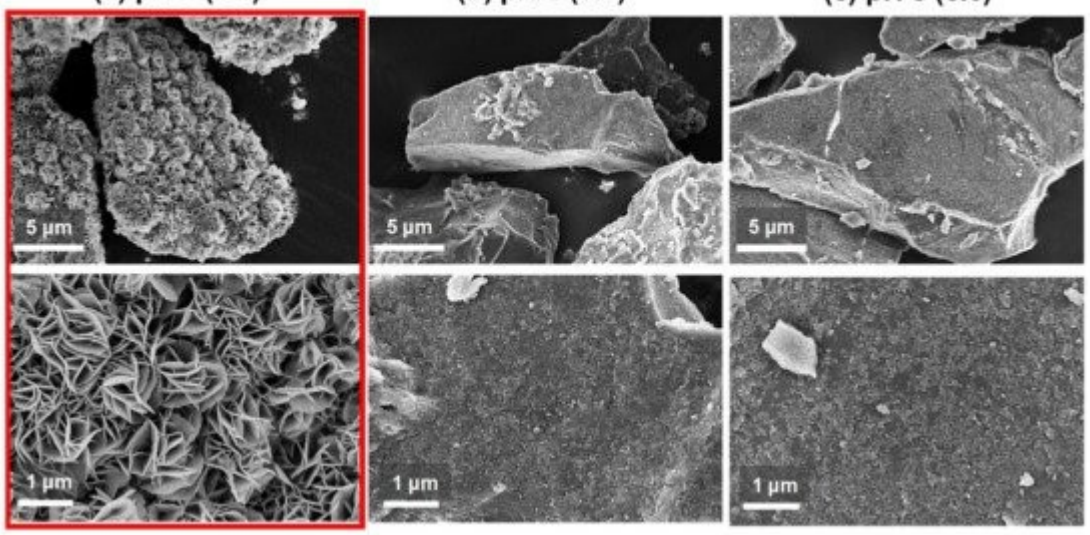

a)
b)
c)


(a)
(b)
(c)

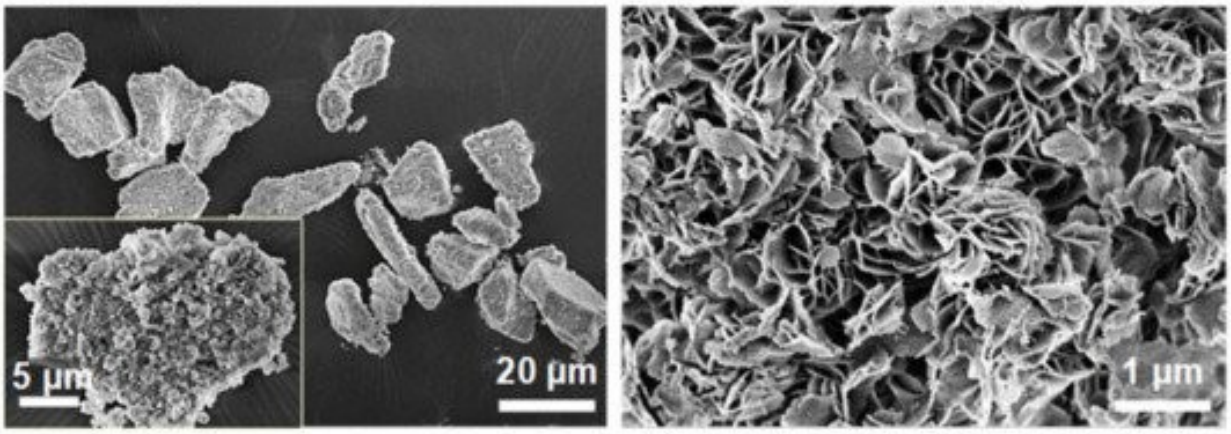

(a)
15kU X5,000 5μm
(b)
15kU X20,000 1μm


1 μm
1 μm

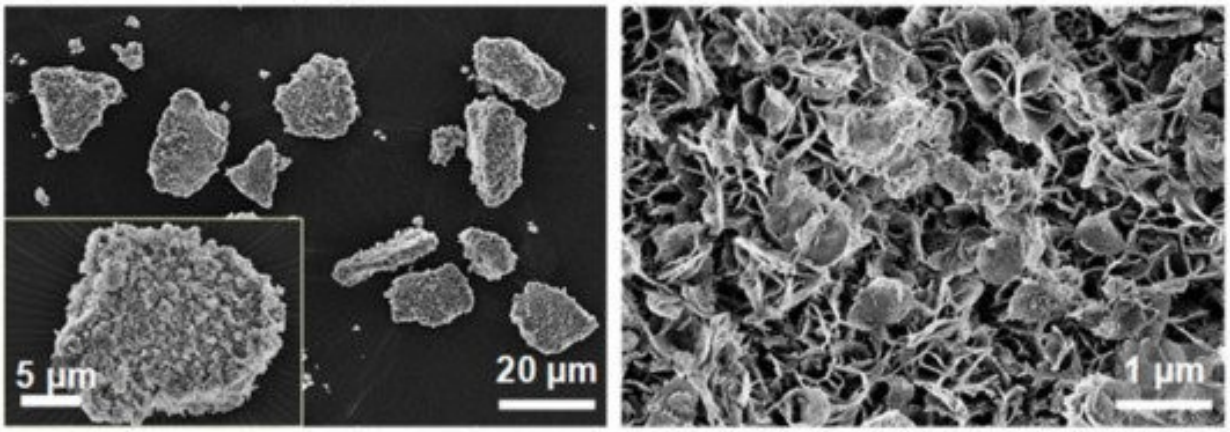
(a) (b)

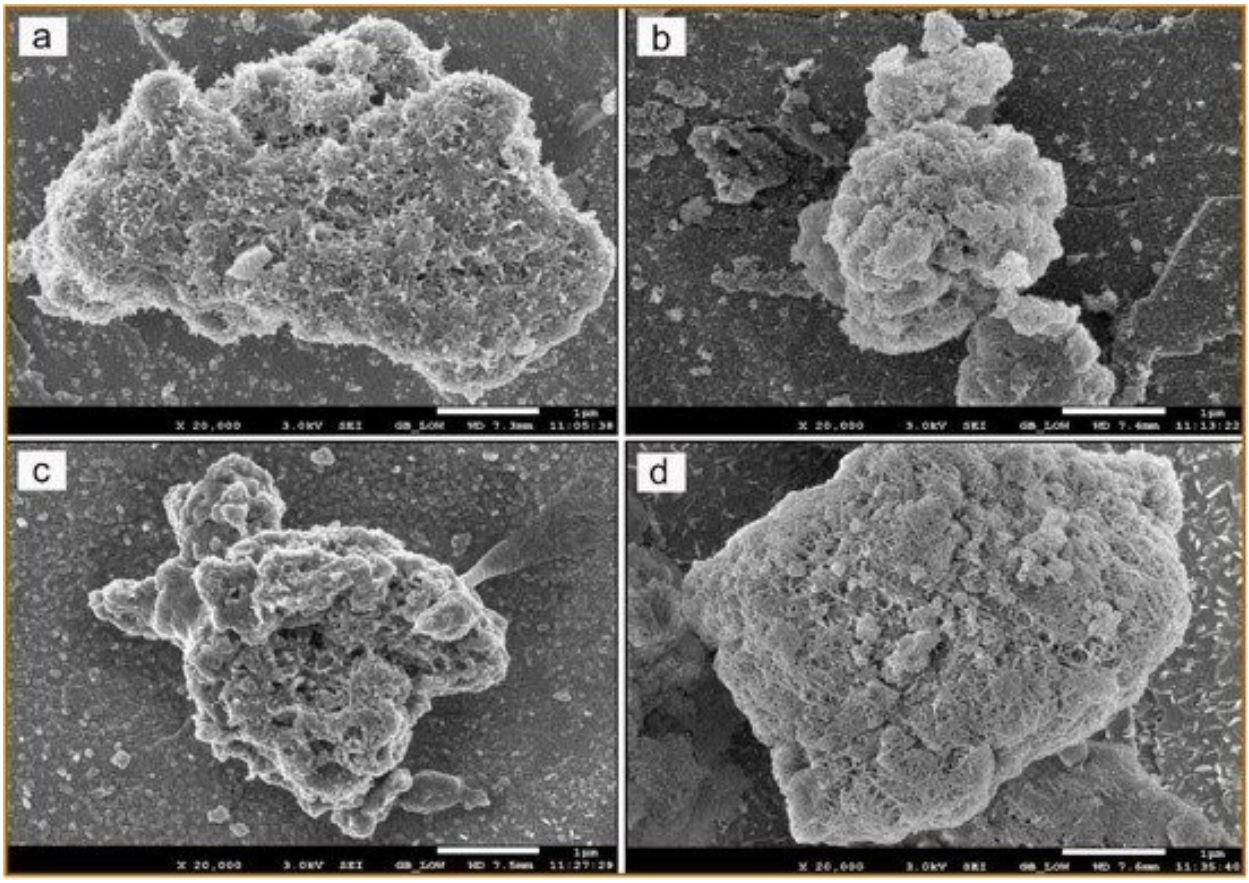

(a) pH 2 (6.1)
(b) pH 5 (7.3)
(c) pH 8 (8.6)
5 μm
5 μm
5 μm
1 μm
1 μm
1 μm

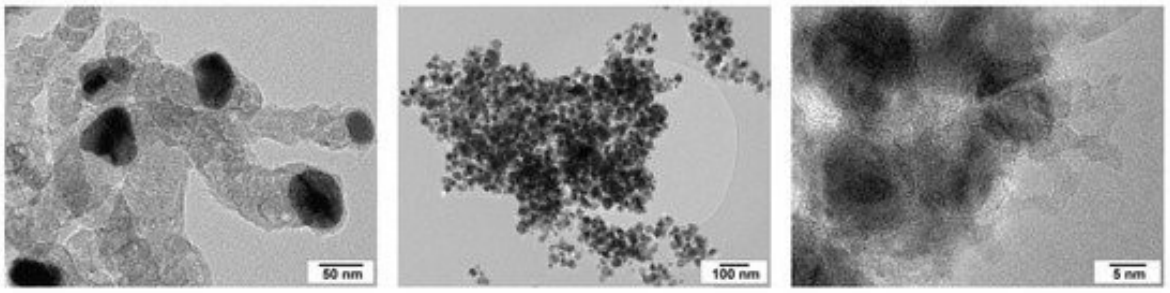
(a) SiC@NiAl-oxide (after calcination)



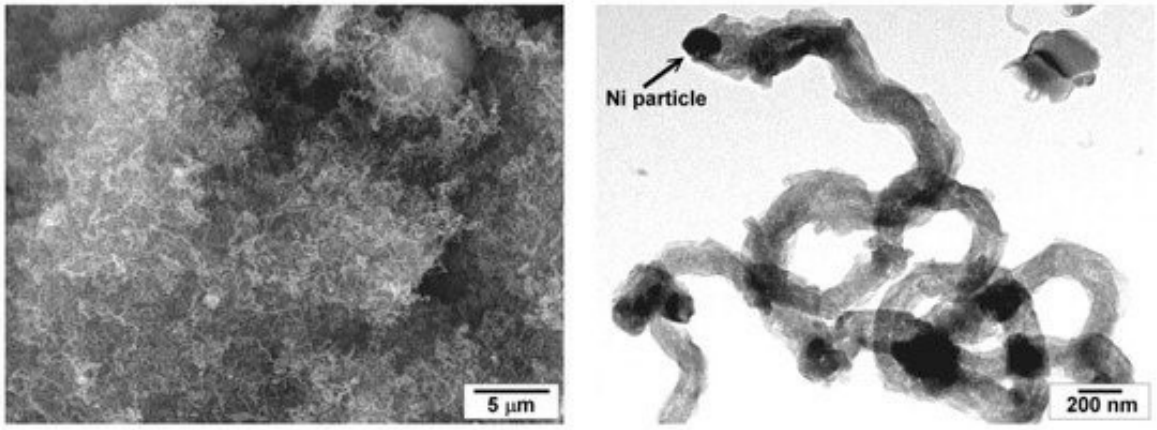
(b) Ni/SiC@Al_2O_3 (after reduction)



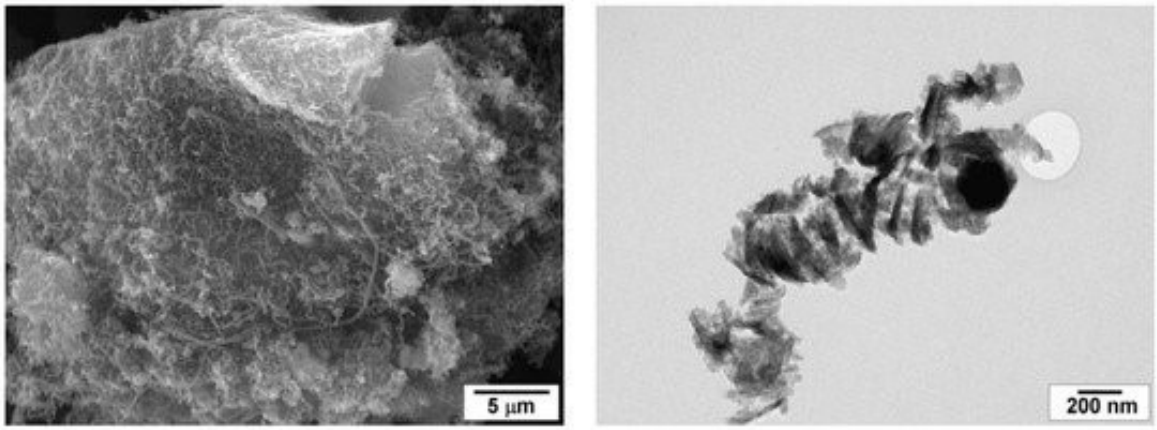




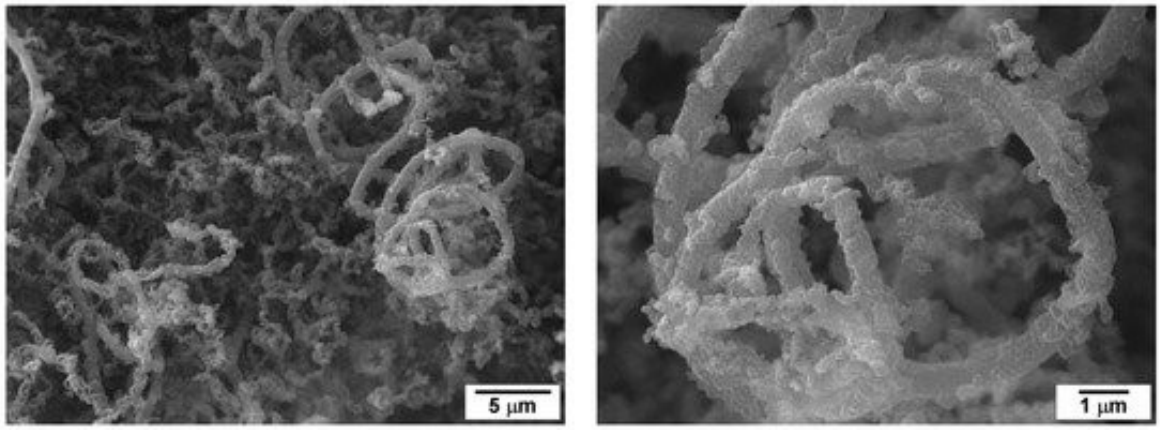
(a) (b) (c)



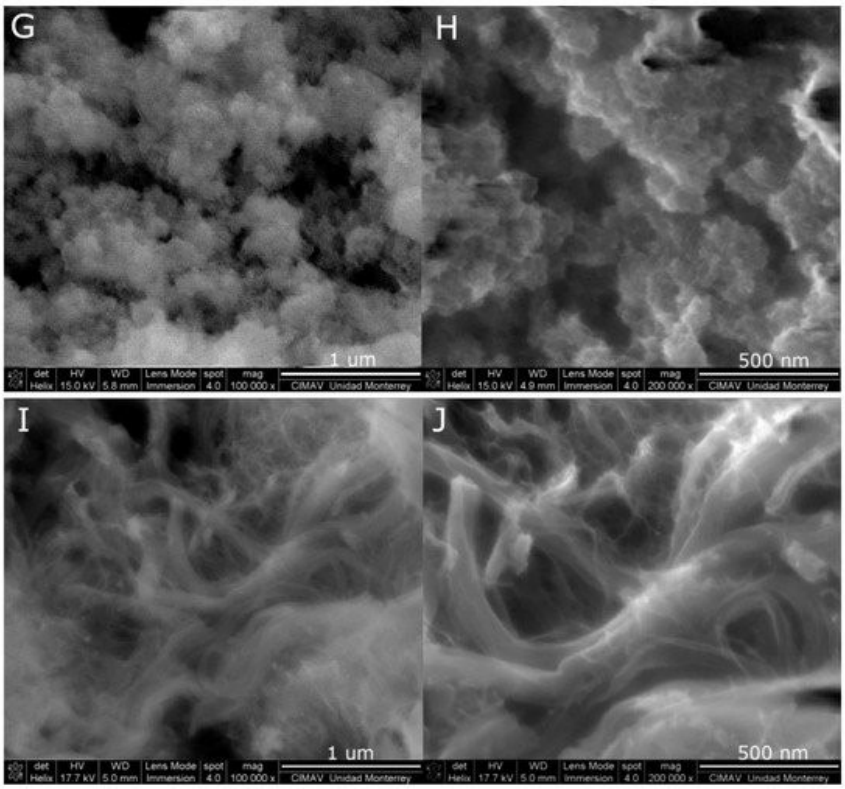
(a) (b)

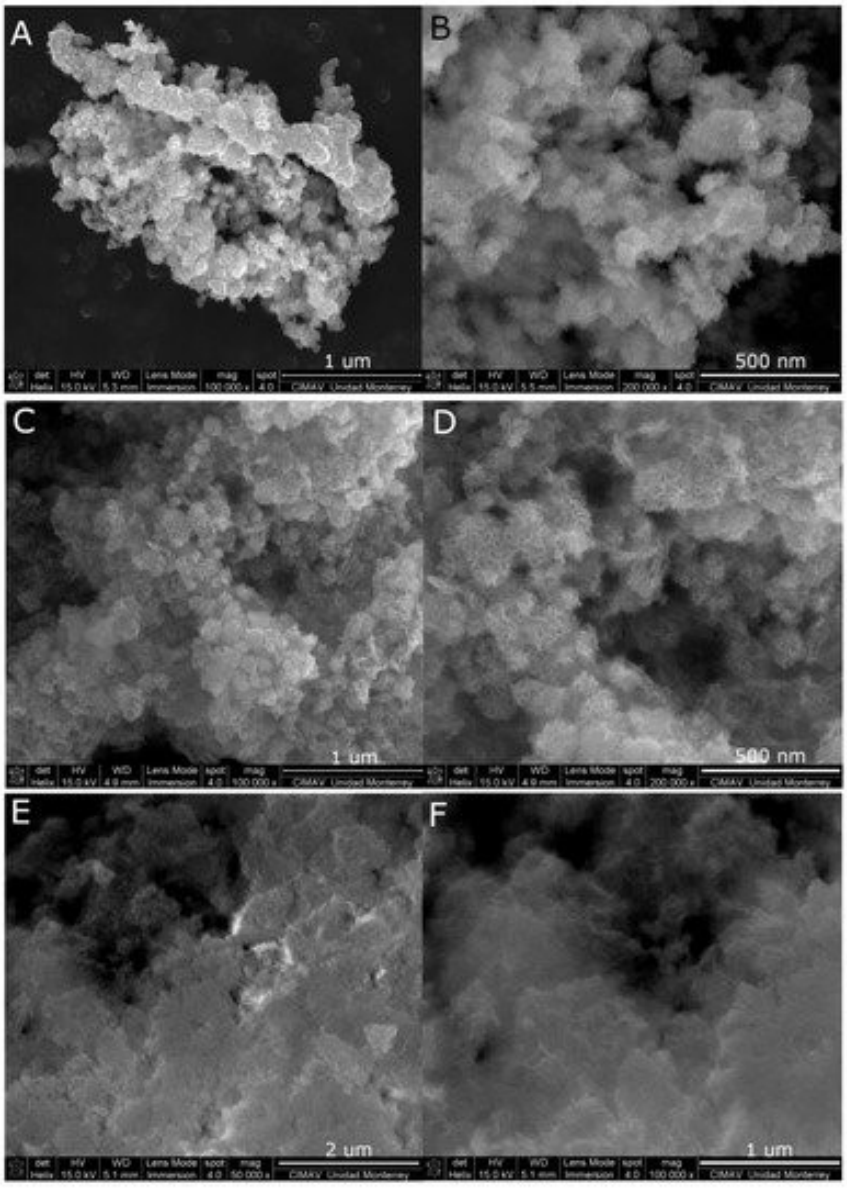


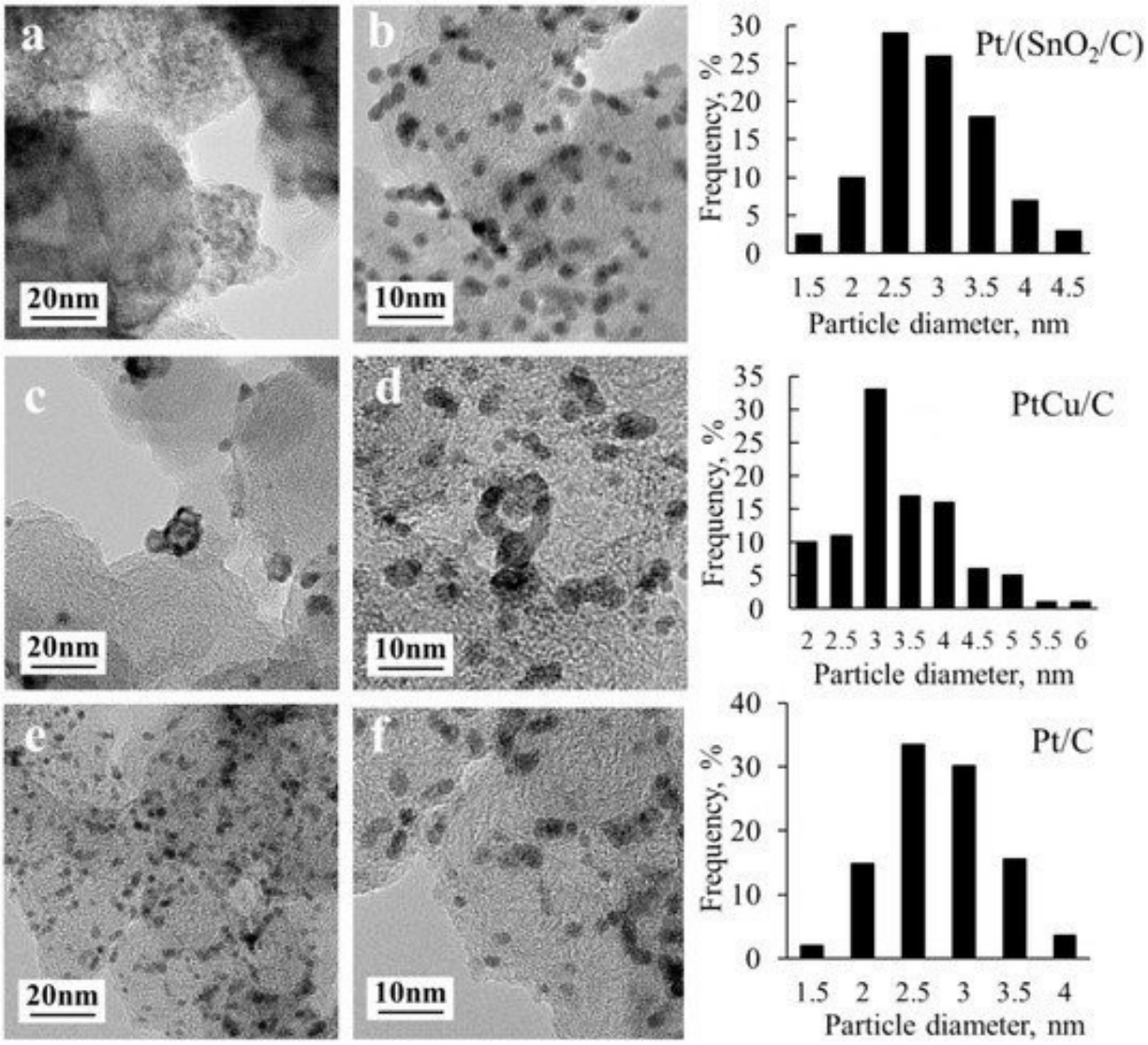
(c) (d)

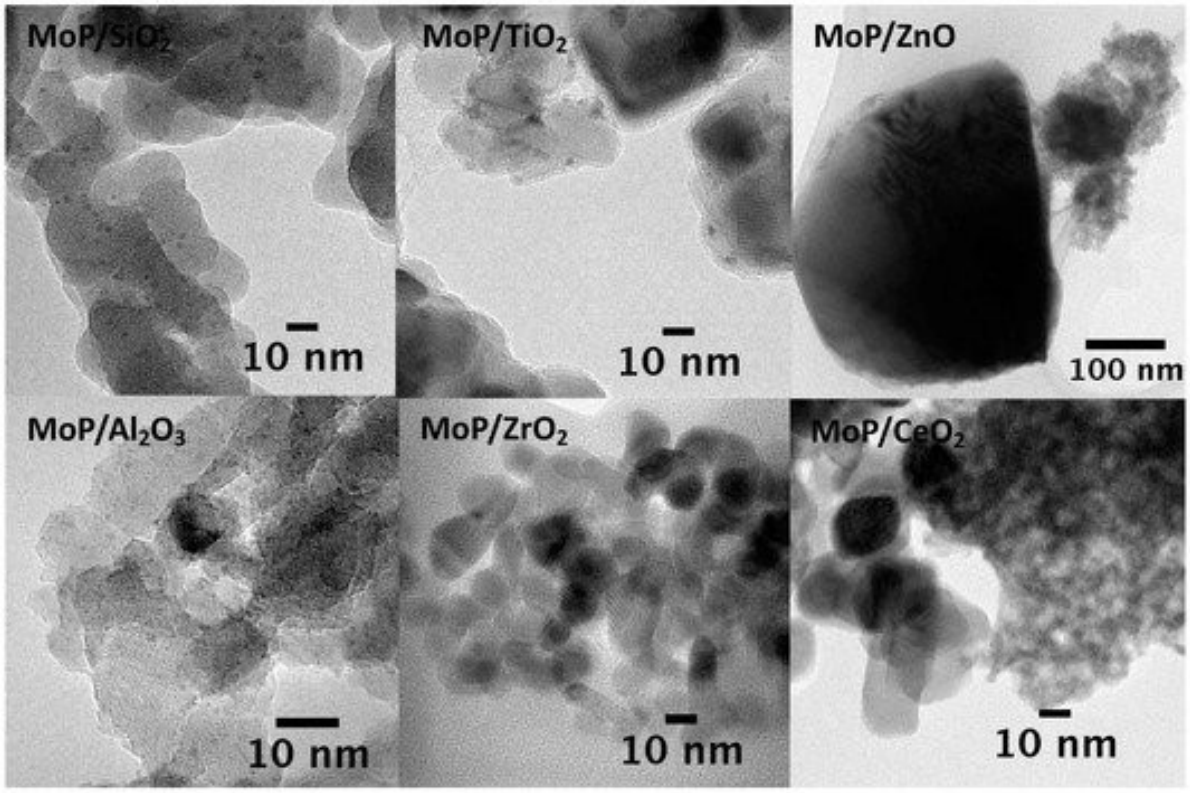


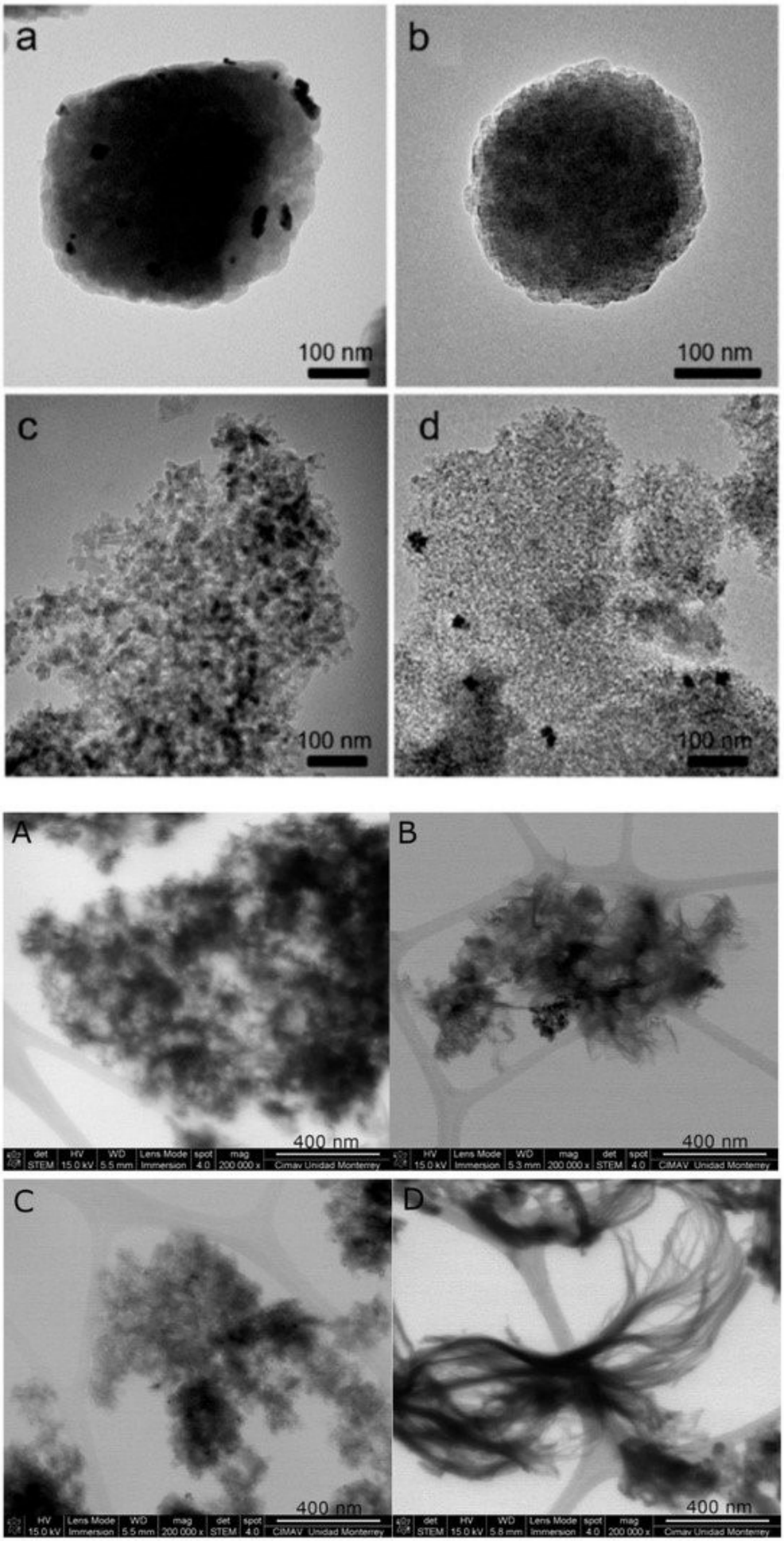
(a) (b)

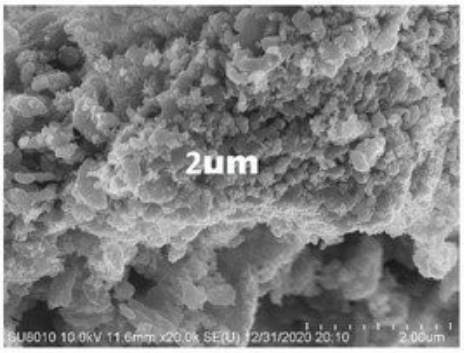

G
1 um
H
500 nm
I
1 um
J
500 nm


A
1 um
B
500 nm
C
1 um
D
500 nm
E
2 um
F
1 um

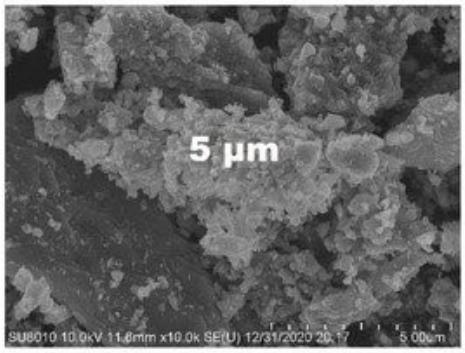

a
20nm
b
10nm
Pt/(SnO2/C)
Frequency, %
30
25
20
15
10
5
0
1.5 2 2.5 3 3.5 4 4.5
Particle diameter, nm
c
20nm
d
10nm
PtCu/C
Frequency, %
35
30
25
20
15
10
5
0
2 2.5 3 3.5 4 4.5 5 5.5 6
Particle diameter, nm
e
20nm
f
10nm
Pt/C
Frequency, %
40
30
20
10
0
1.5 2 2.5 3 3.5 4
Particle diameter, nm


MoP/SiO2
10 nm
MoP/TiO2
10 nm
MoP/ZnO
100 nm
MoP/Al2O3
10 nm
MoP/ZrO2
10 nm
MoP/CeO2
10 nm

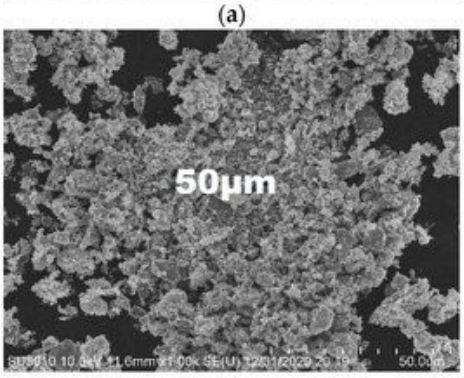

a
100 nm
b
100 nm
c
100 nm
d
100 nm
A
400 nm
B
400 nm
C
400 nm
D
400 nm



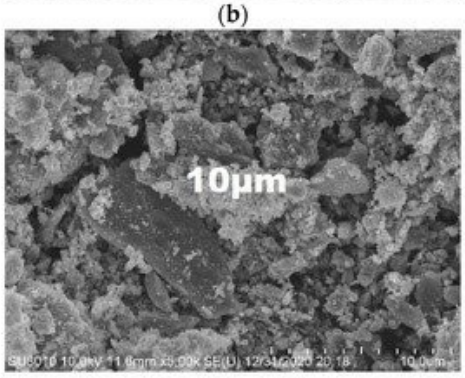
(a)



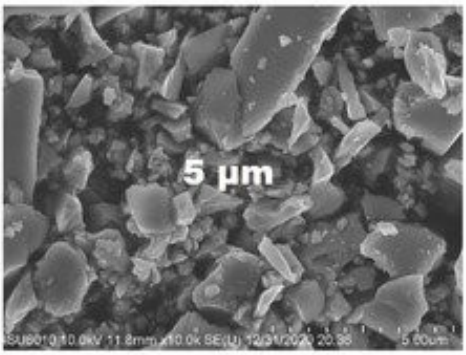
(b)



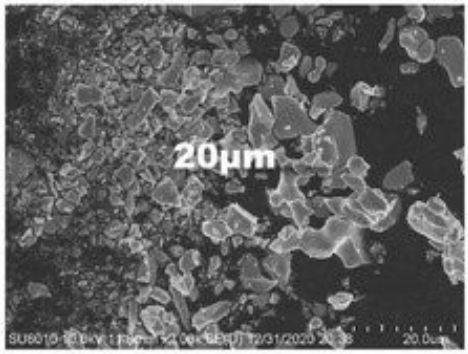
(c)



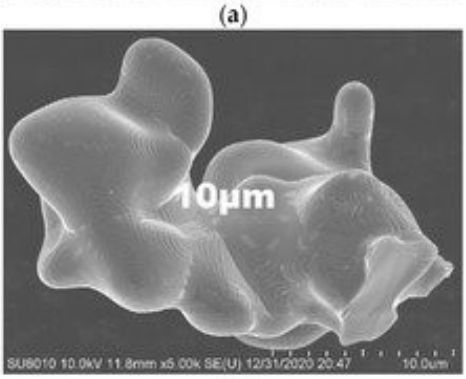
(d)



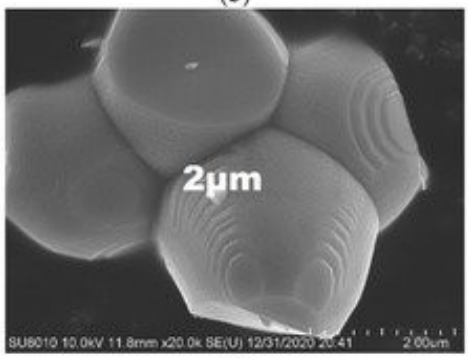
(a)



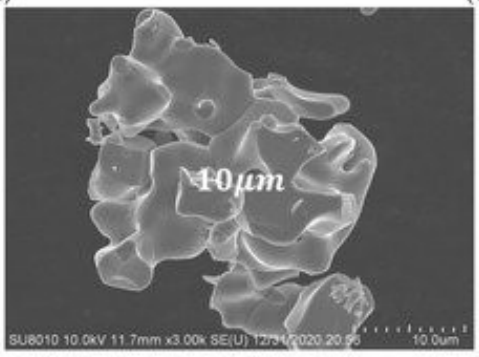
(b)



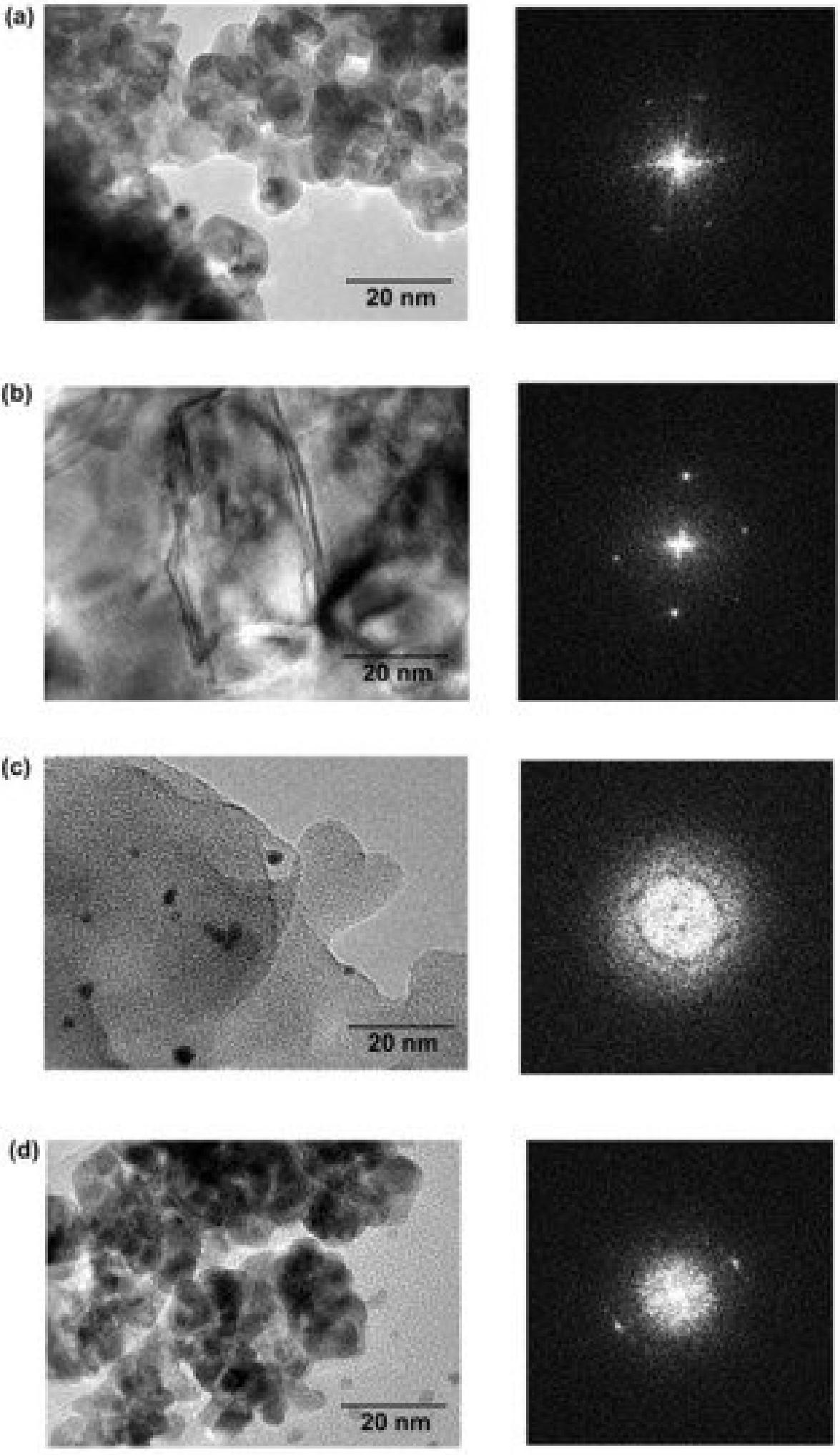
(c)

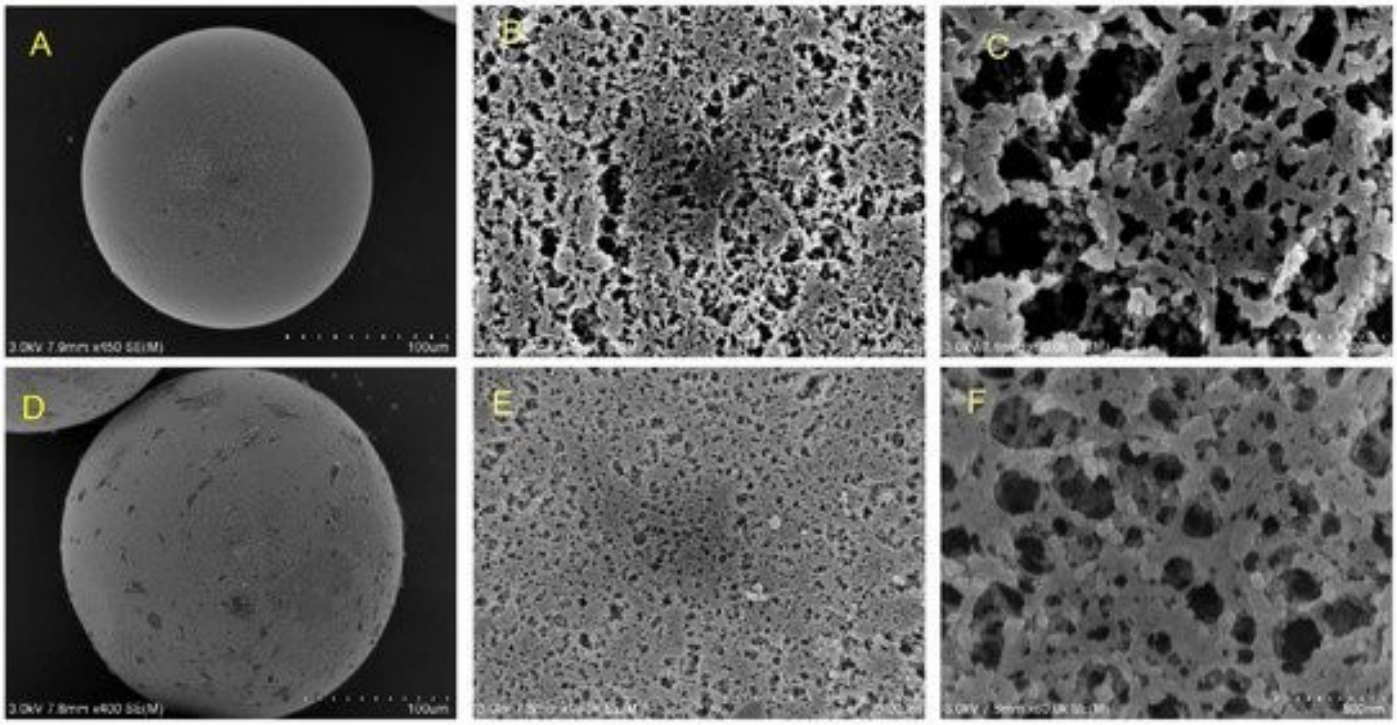


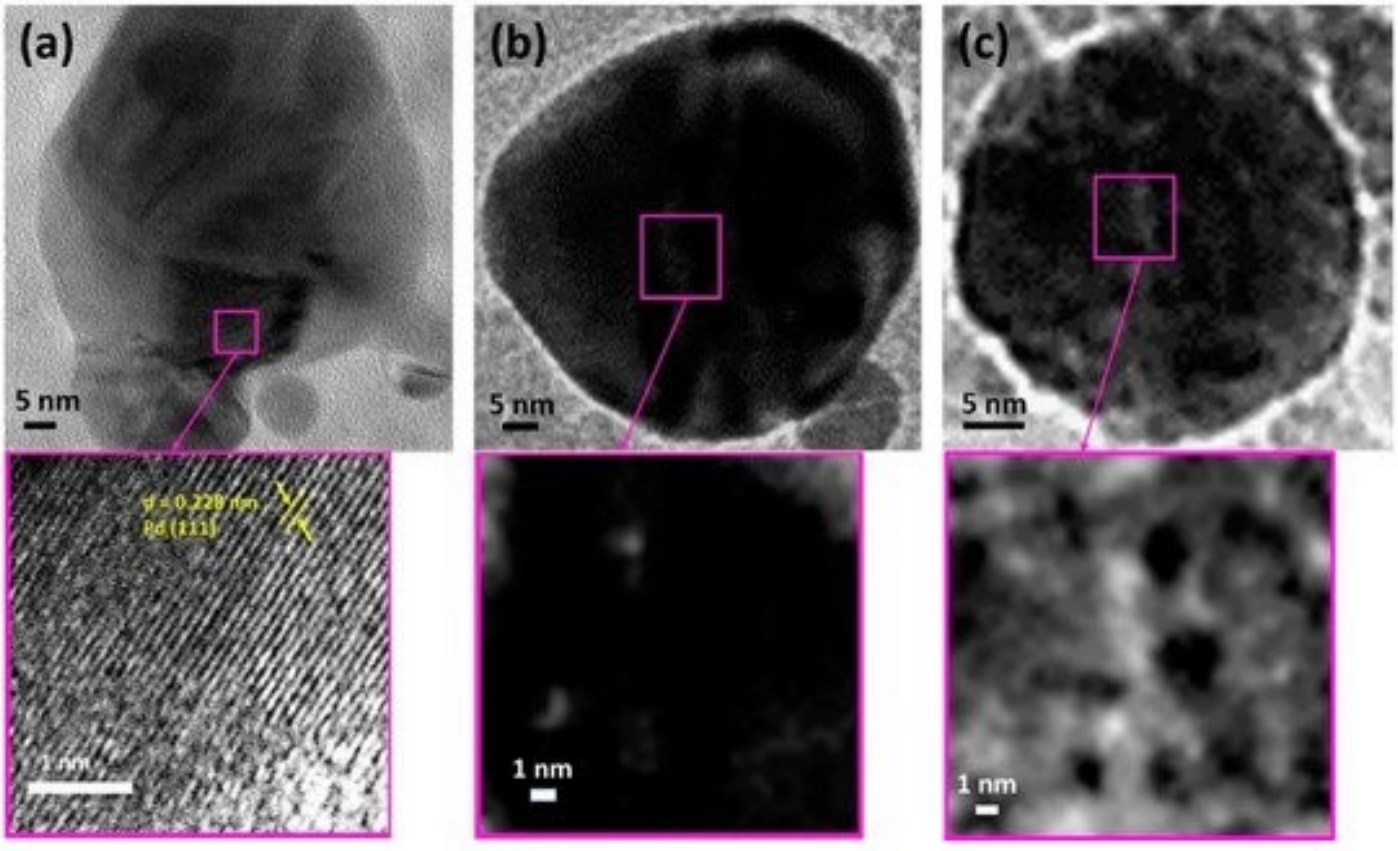
(d)

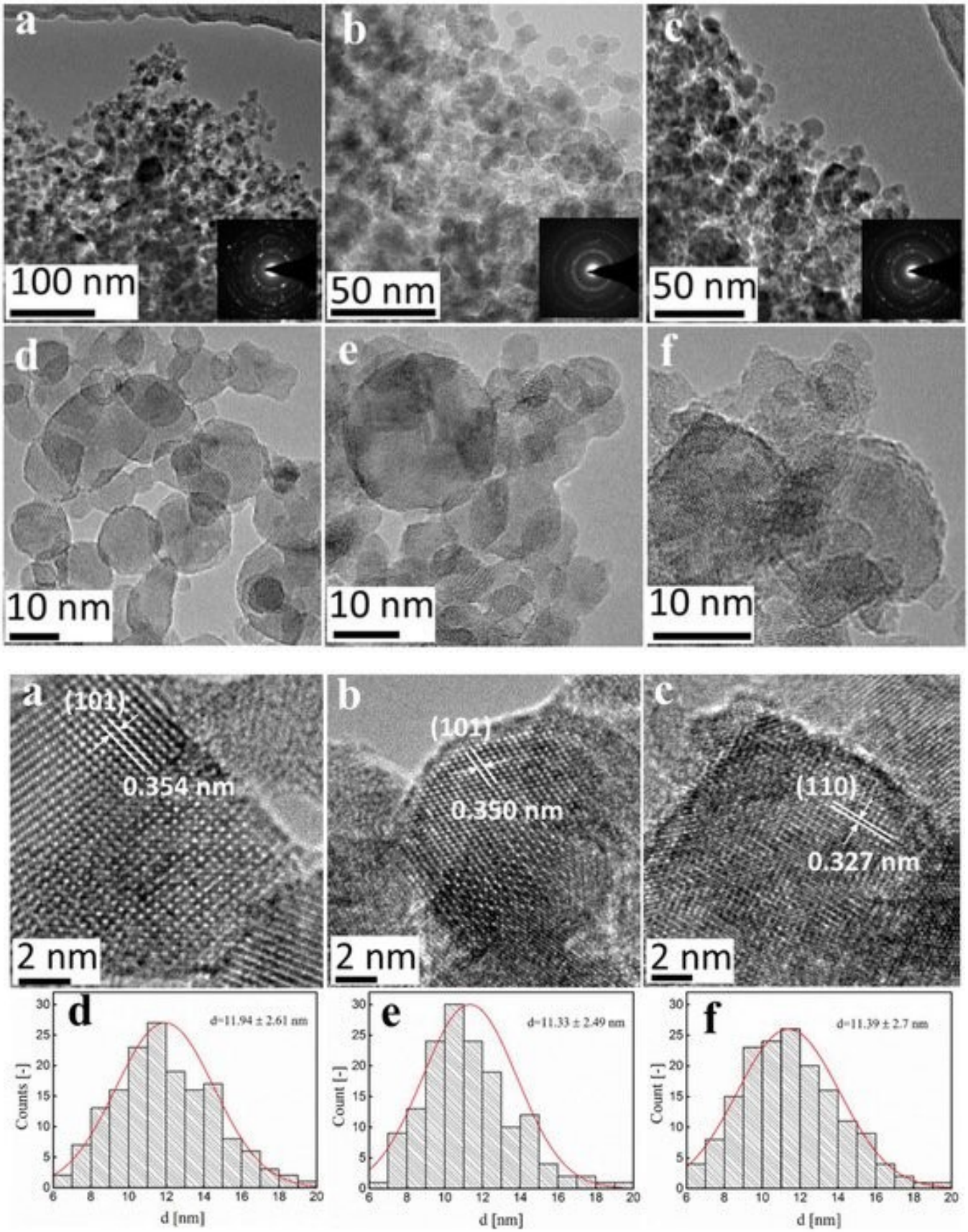


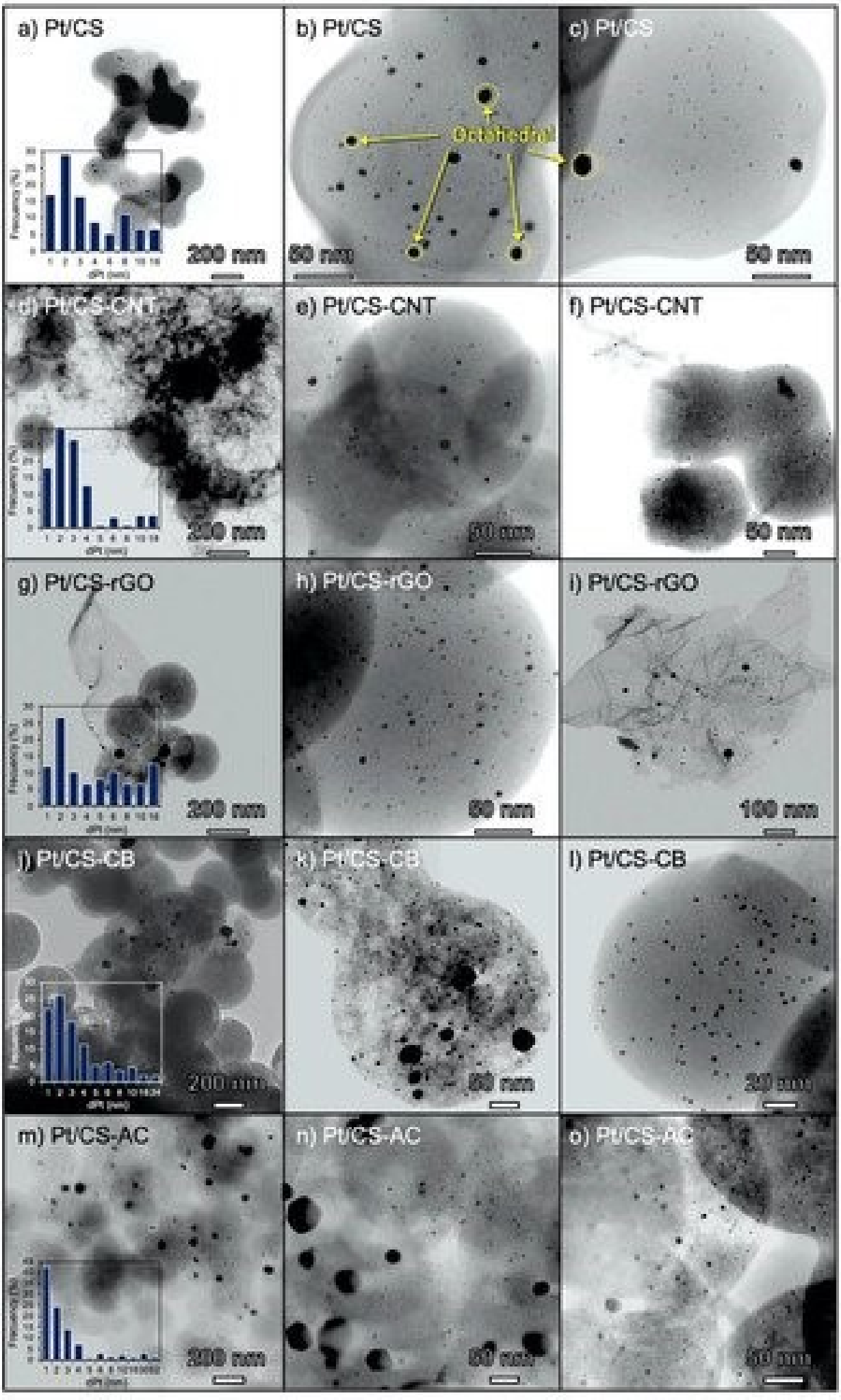
(e)

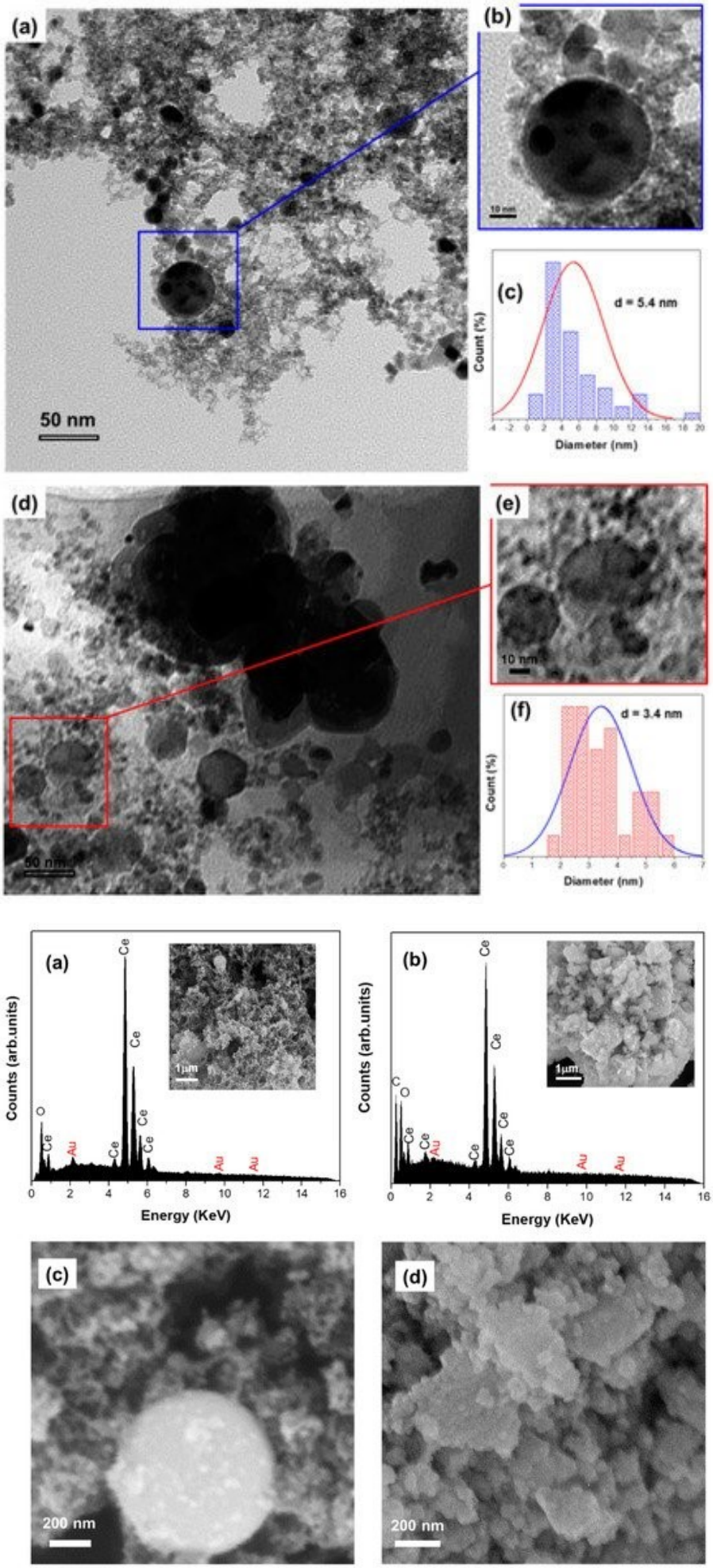

(a)
20 nm
(b)
20 nm
(c)
20 nm
(d)
20 nm

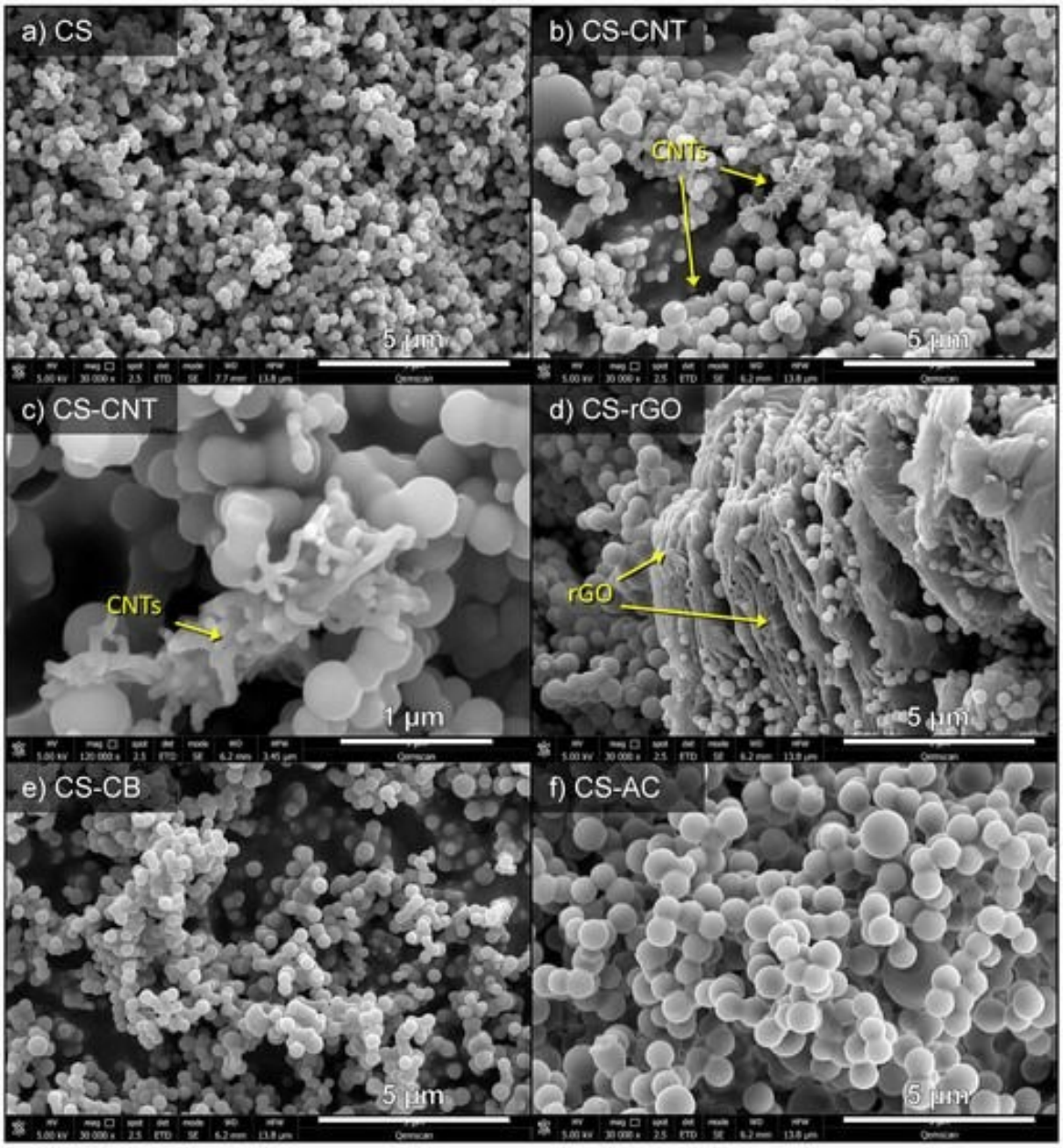

A
B
C
D
E
F

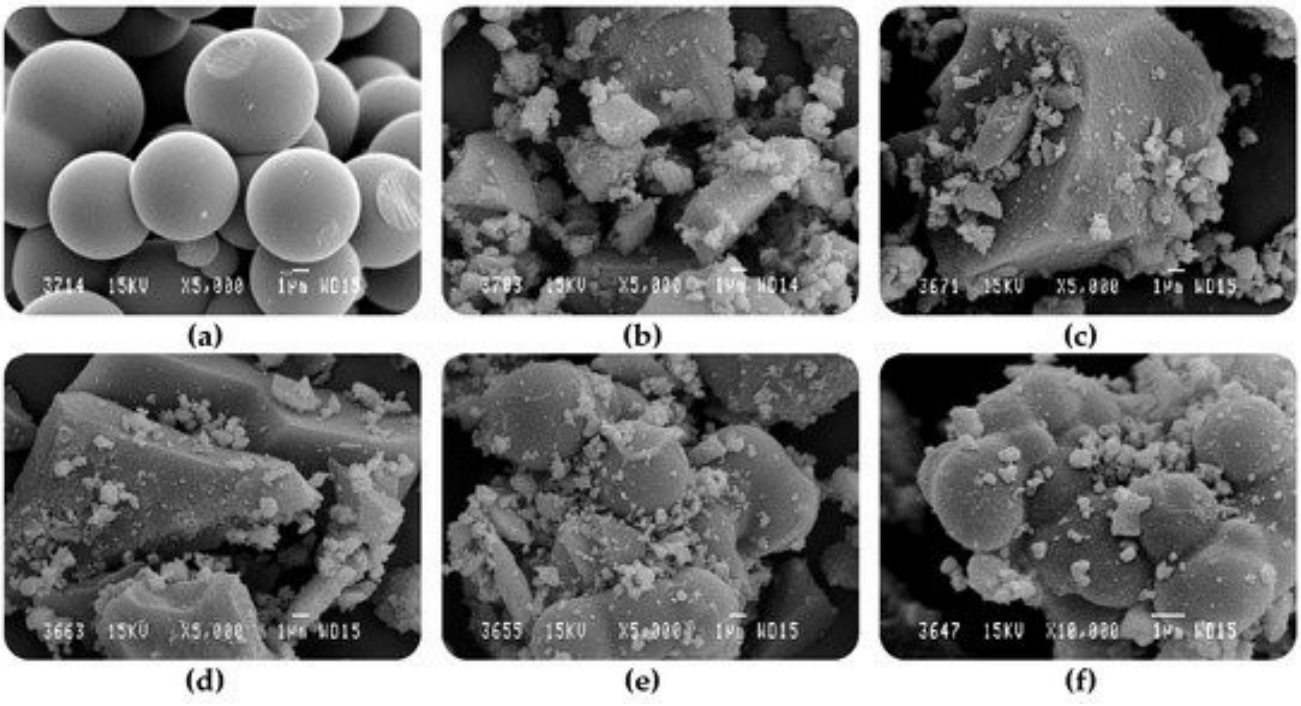

(a)
(b)
(c)
5 nm
5 nm
5 nm
d = 0.228 nm
Pd (111)
1 nm
1 nm
1 nm

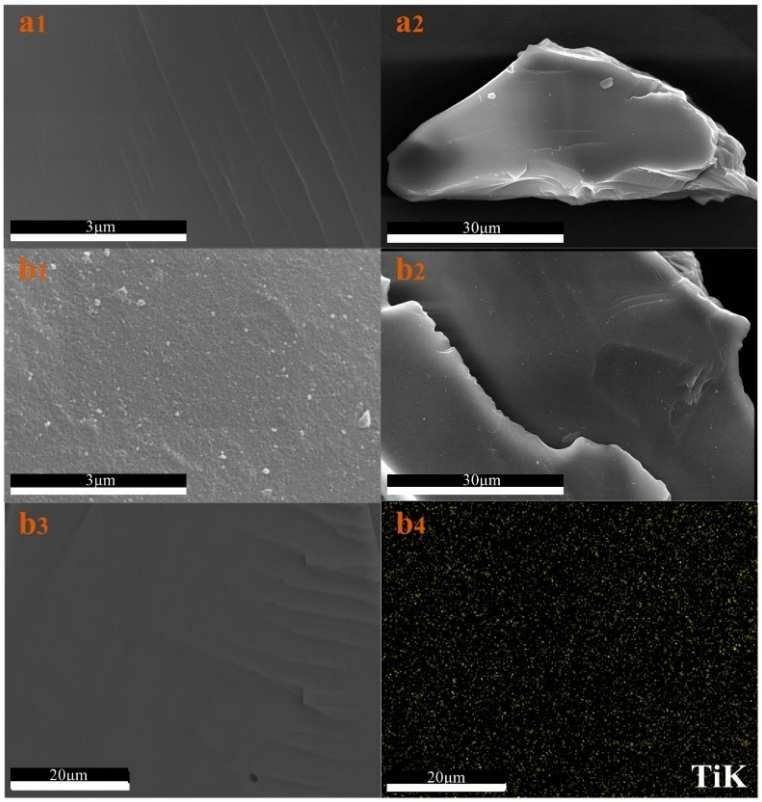

a
100 nm
b
50 nm
c
50 nm
d
10 nm
e
10 nm
f
10 nm
a
(101)
0.354 nm
2 nm
b
(101)
0.350 nm
2 nm
c
(110)
0.327 nm
2 nm
d
d=11.94 ± 2.61 nm
Counts [-]
d [nm]
e
d=11.33 ± 2.49 nm
Count [-]
d [nm]
f
d=11.39 ± 2.7 nm
Count [-]
d [nm]

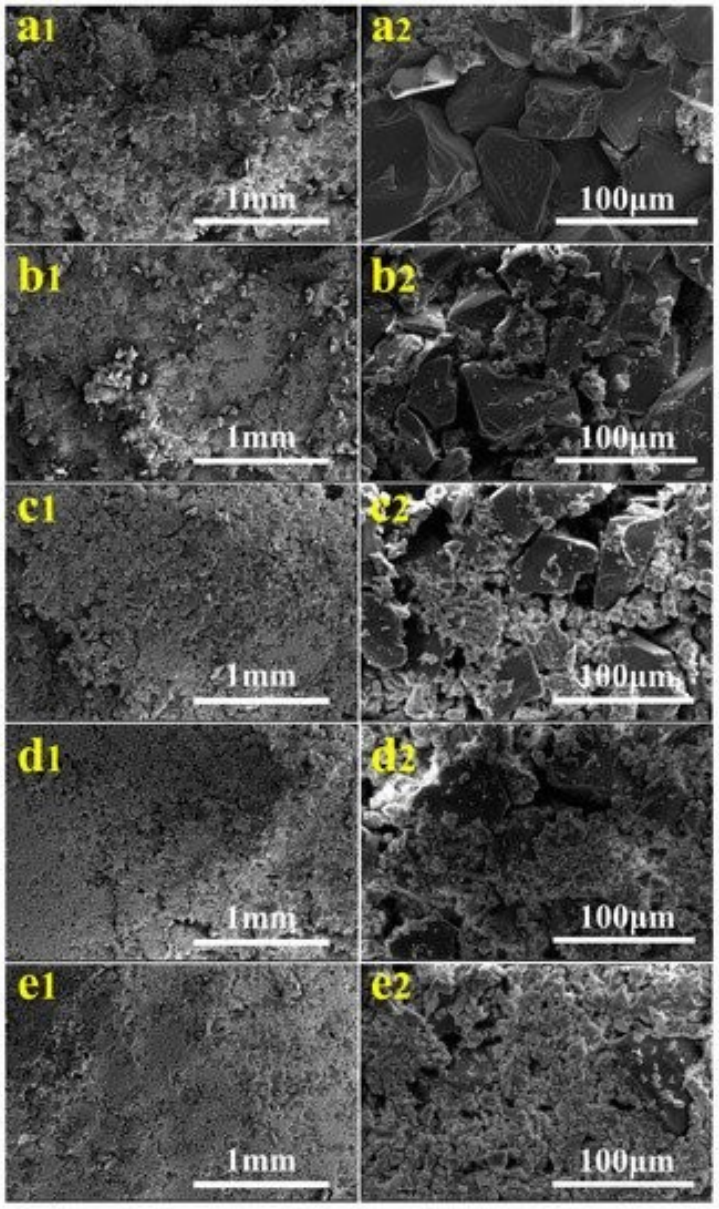

a) Pt/CS
200 nm
b) Pt/CS
Octahedral
50 nm
c) Pt/CS
50 nm
d) Pt/CS-CNT
200 nm
e) Pt/CS-CNT
50 nm
f) Pt/CS-CNT
50 nm
g) Pt/CS-rGO
200 nm
h) Pt/CS-rGO
50 nm
i) Pt/CS-rGO
100 nm
j) Pt/CS-CB
200 nm
k) Pt/CS-CB
50 nm
l) Pt/CS-CB
20 nm
m) Pt/CS-AC
200 nm
n) Pt/CS-AC
50 nm
o) Pt/CS-AC
50 nm

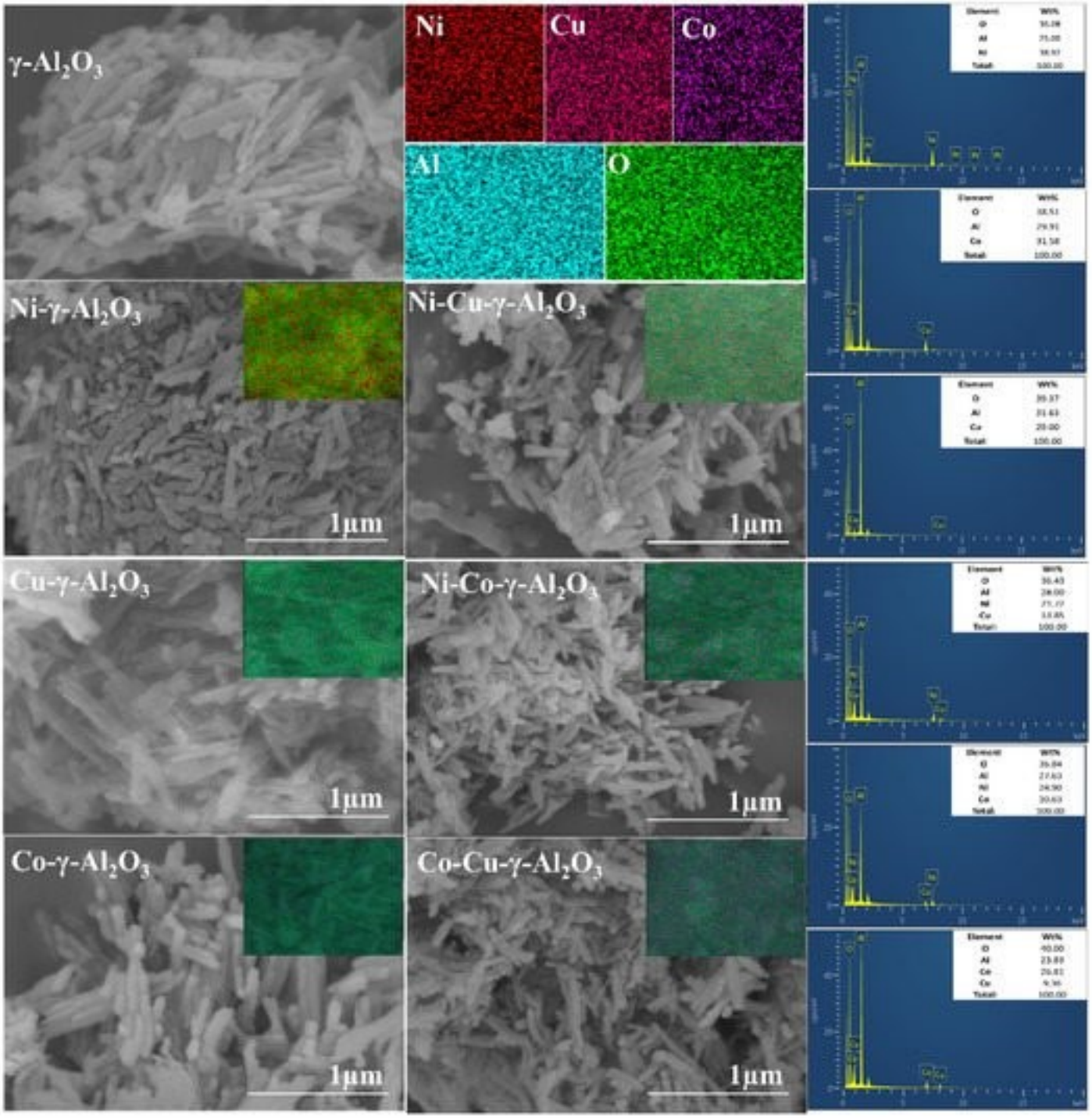

(a)
50 nm
(b)
10 nm
(c)
d = 5.4 nm
Count (%)
Diameter (nm)
(d)
50 nm
(e)
10 nm
(f)
d = 3.4 nm
Count (%)
Diameter (nm)
(a)
Counts (arb.units)
Ce
O
Au
1μm
Energy (KeV)
(b)
Counts (arb.units)
C
O
Ce
Au
1μm
Energy (KeV)
(c)
200 nm
(d)
200 nm

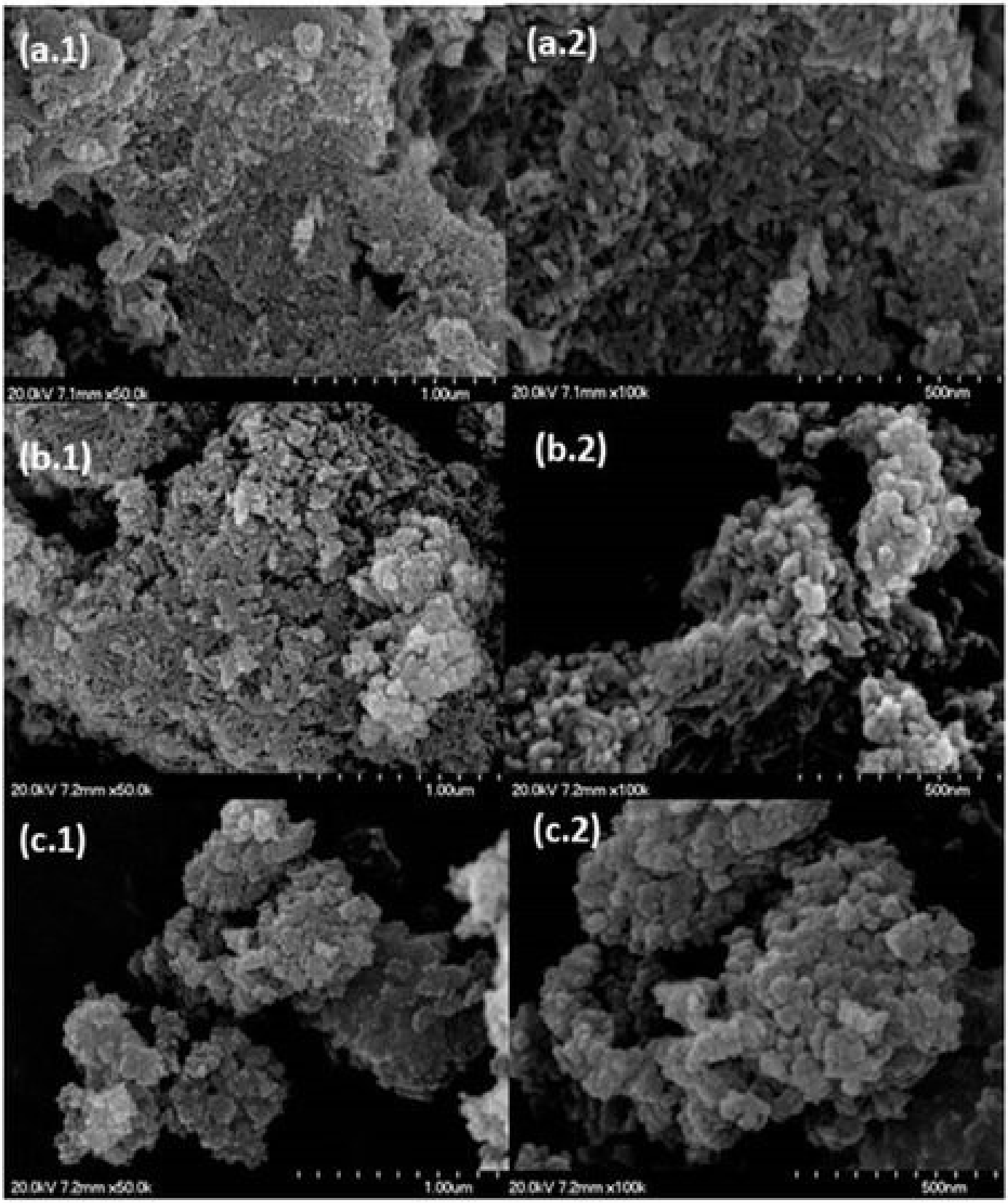

a) CS
5 µm
b) CS-CNT
CNTs
5 µm
c) CS-CNT
CNTs
1 µm
d) CS-rGO
rGO
5 µm
e) CS-CB
5 µm
f) CS-AC
5 µm

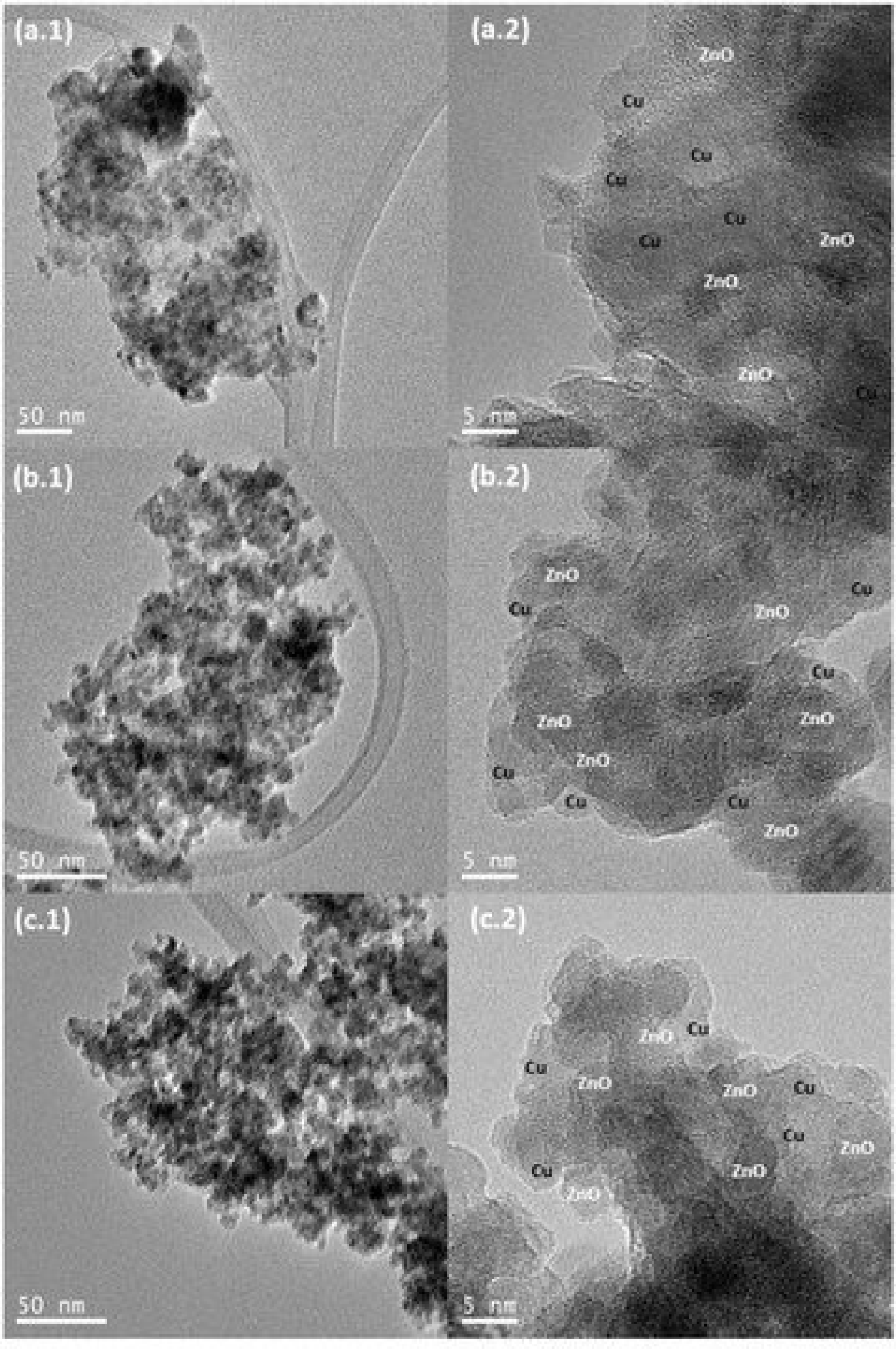

(a)
(b)
(c)
(d)
(e)
(f)

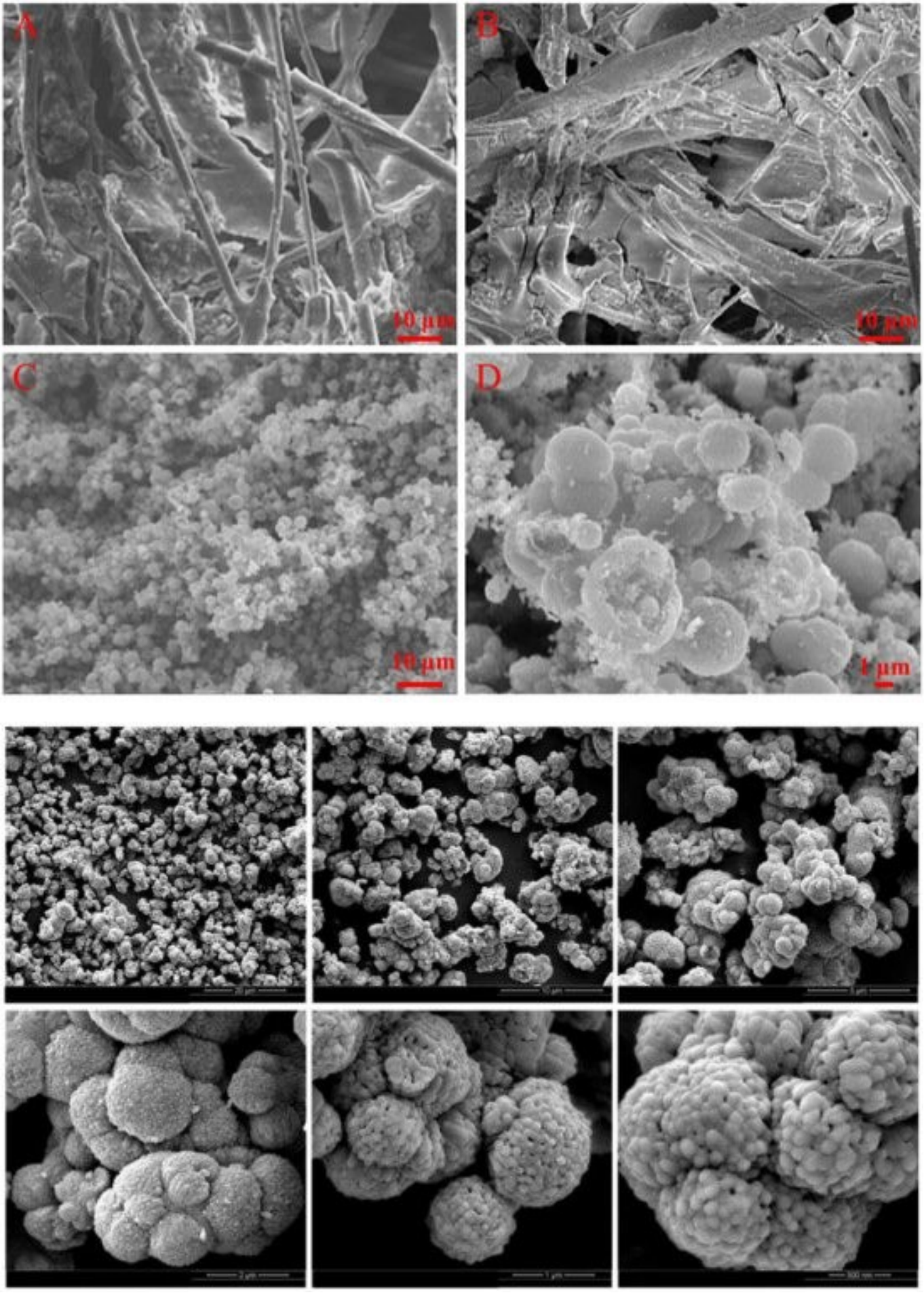

a1
3μm
a2
30μm
b1
3μm
b2
30μm
b3
20μm
b4
20μm
TiK

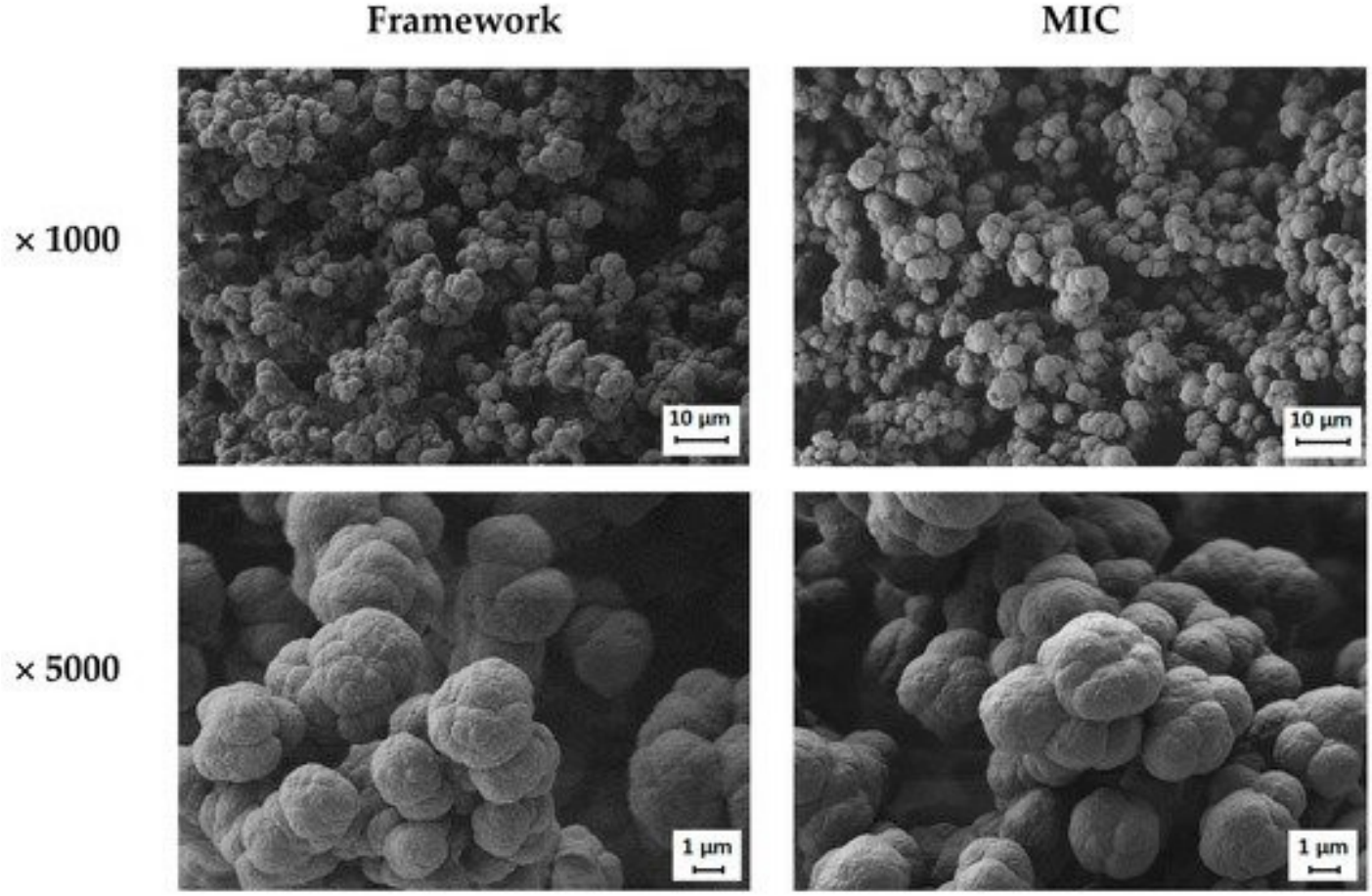

a1
1mm
a2
100μm
b1
1mm
b2
100μm
c1
1mm
c2
100μm
d1
1mm
d2
100μm
e1
1mm
e2
100μm

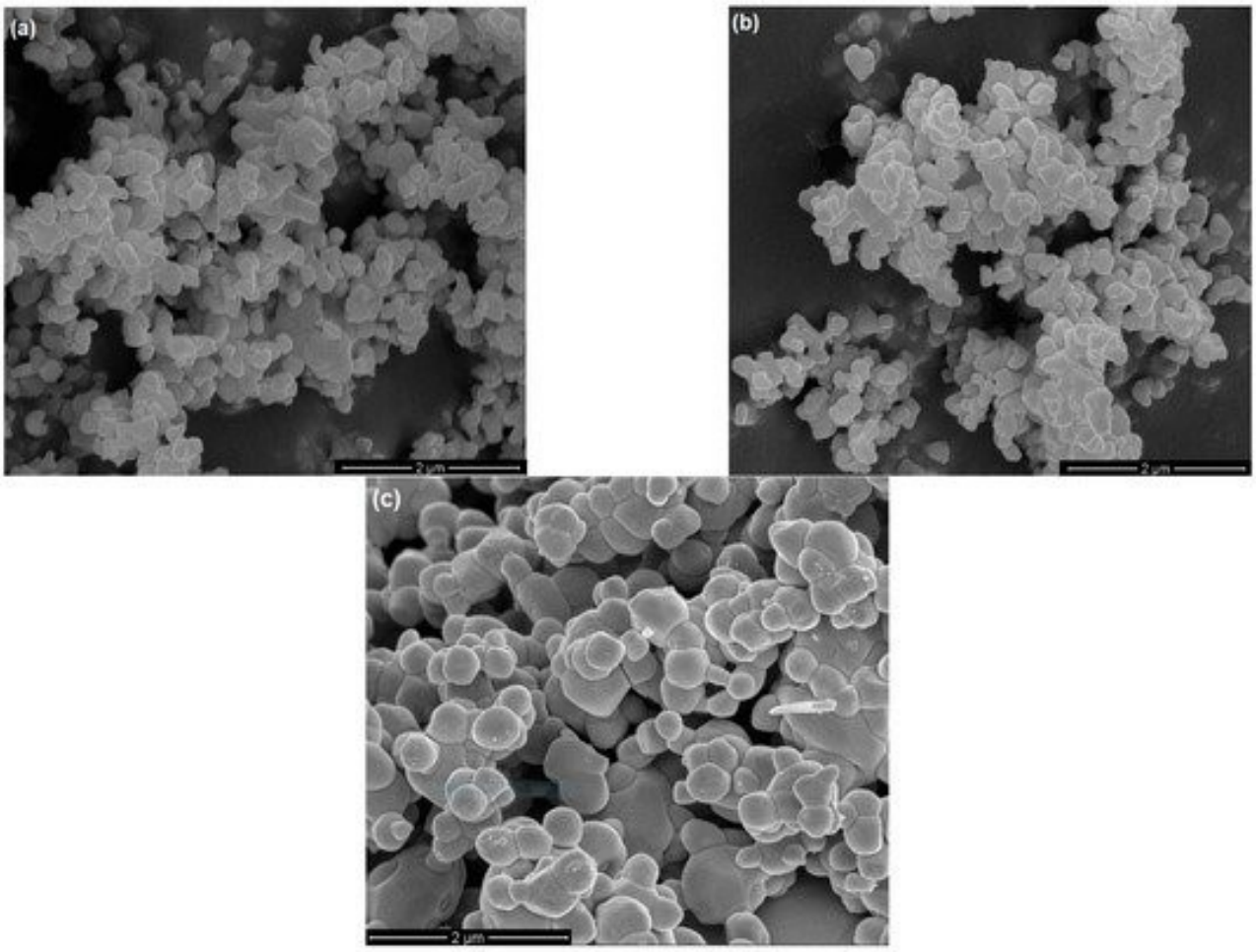

γ-Al2O3
Ni
Cu
Co
Al
O
Ni-γ-Al2O3
Ni-Cu-γ-Al2O3
Cu-γ-Al2O3
Ni-Co-γ-Al2O3
Co-γ-Al2O3
Co-Cu-γ-Al2O3
1μm

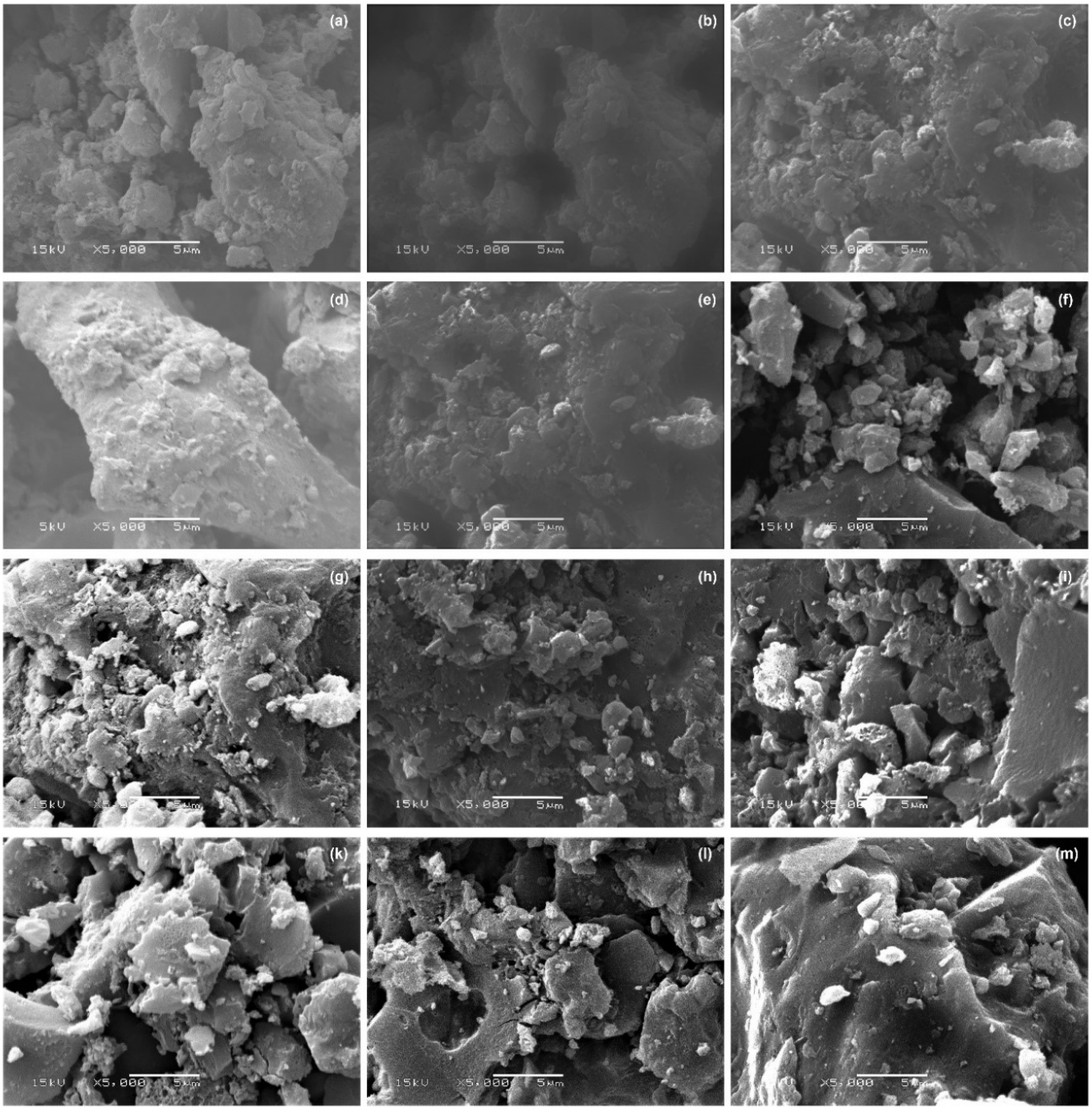

(a.1)
20.0kV 7.1mm x50.0k
1.00μm
(a.2)
20.0kV 7.1mm x100k
500nm
(b.1)
20.0kV 7.2mm x50.0k
1.00μm
(b.2)
20.0kV 7.2mm x100k
500nm
(c.1)
20.0kV 7.2mm x50.0k
1.00μm
(c.2)
20.0kV 7.2mm x100k
500nm

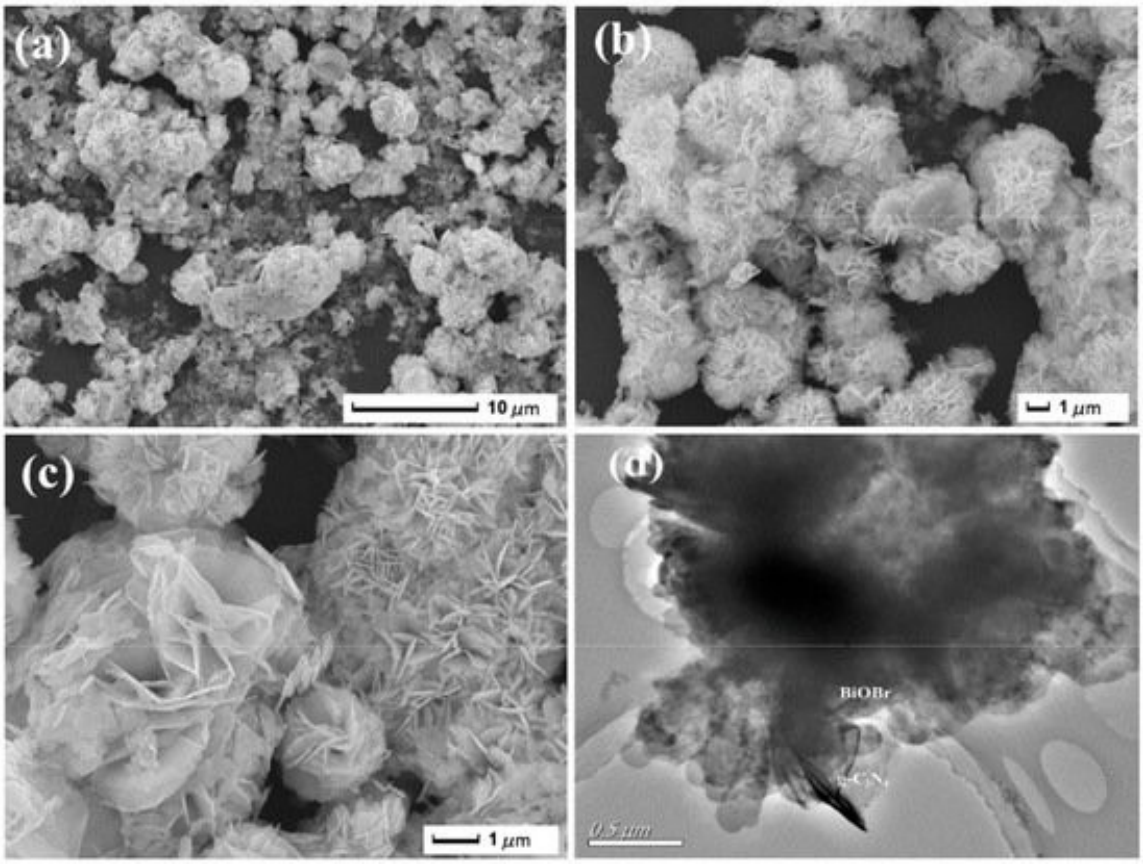

(a.1)
50 nm
(a.2)
ZnO
Cu
Cu
Cu
Cu
ZnO
ZnO
ZnO
Cu
5 nm
(b.1)
50 nm
(b.2)
ZnO
Cu
Cu
ZnO
Cu
ZnO
ZnO
Cu
ZnO
Cu
Cu
ZnO
5 nm
(c.1)
50 nm
(c.2)
ZnO
Cu
Cu
ZnO
ZnO
Cu
Cu
ZnO
Cu
ZnO
ZnO
5 nm

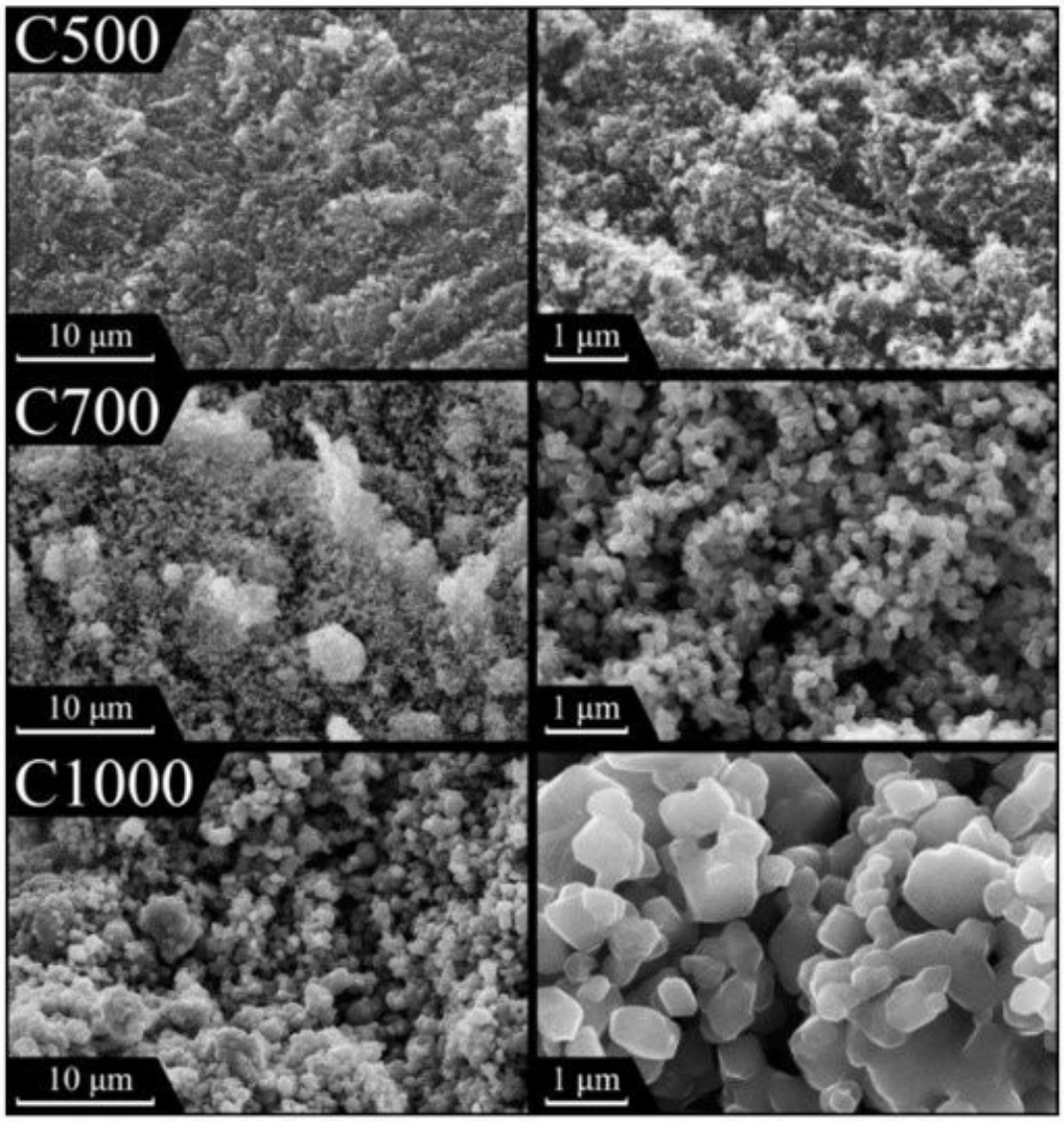

A
10 μm
B
10 μm
C
10 μm
D
1 μm

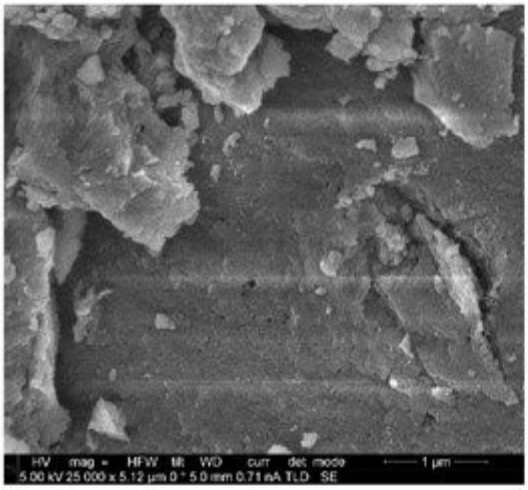

Framework
MIC
× 1000
× 5000
10 μm
10 μm
1 μm
1 μm


(a)
(b)
(c)
2 μm
2 μm
2 μm

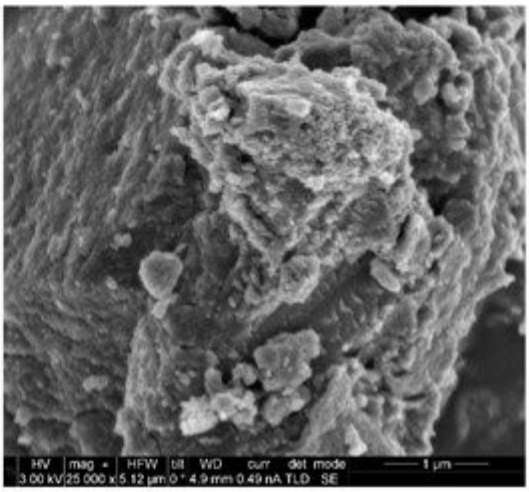

(a)
15kV X5,000 5μm
(b)
15kV X5,000 5μm
(c)
15kV X5,000 5μm
(d)
5kV X5,000 5μm
(e)
15kV X5,000 5μm
(f)
15kV X5,000 5μm
(g)
15kV
(h)
15kV X5,000 5μm
(i)
15kV
(k)
15kV X5,000 5μm
(l)
15kV X5,000 5μm
(m)
X5,000


(a)
10 μm
(b)
1 μm
(c)
1 μm
(d)
BiOBr
0.5 μm

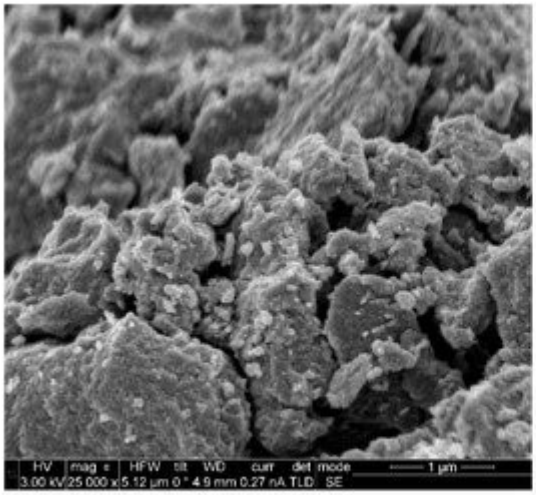

C500
10 μm
1 μm
C700
10 μm
1 μm
C1000
10 μm
1 μm



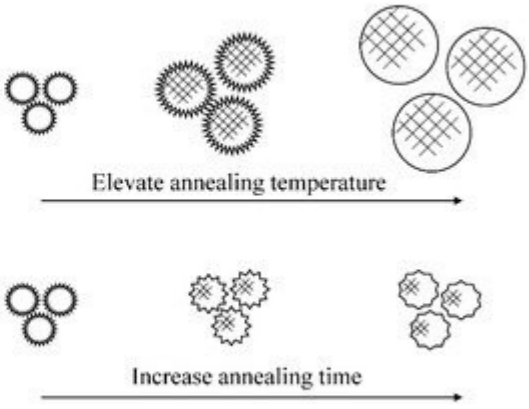
(a)



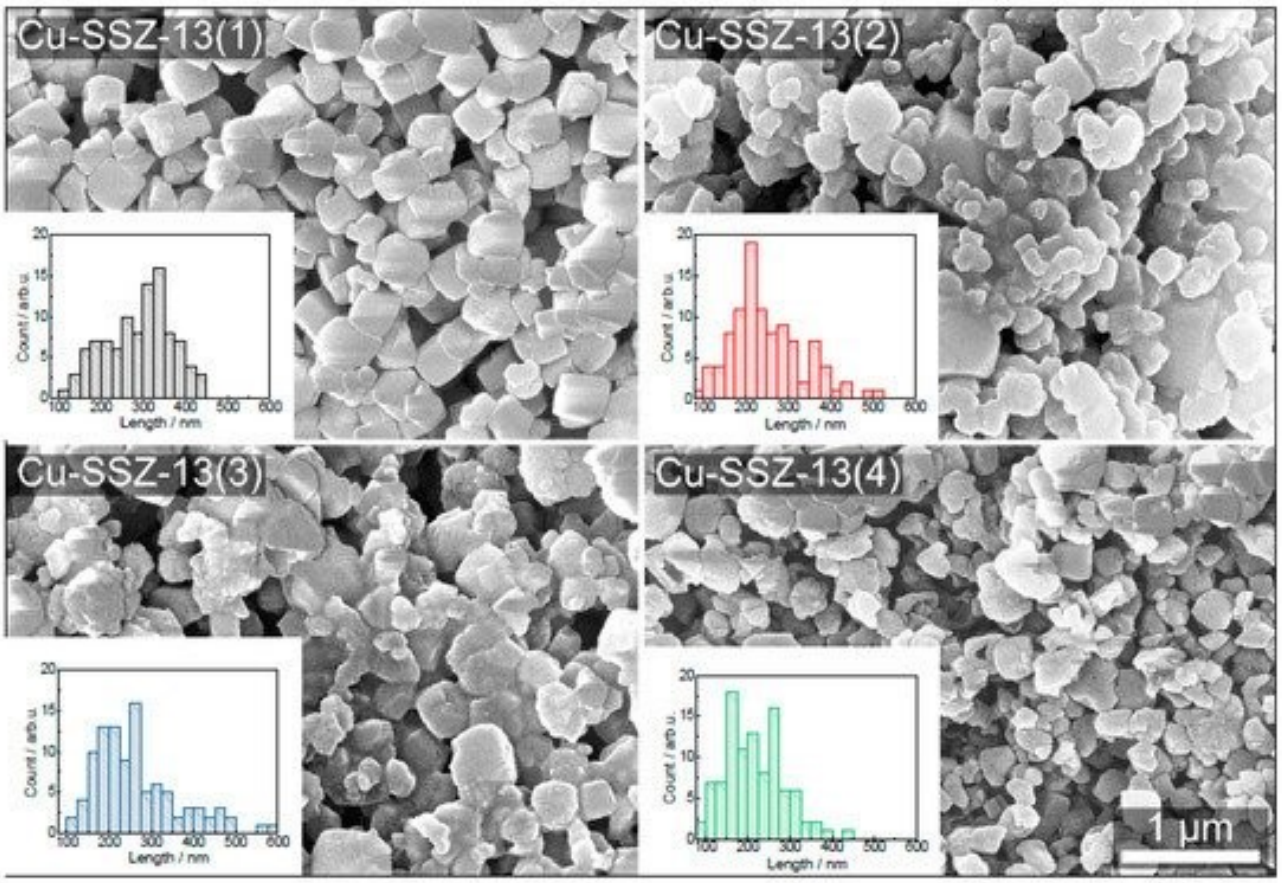
(b)

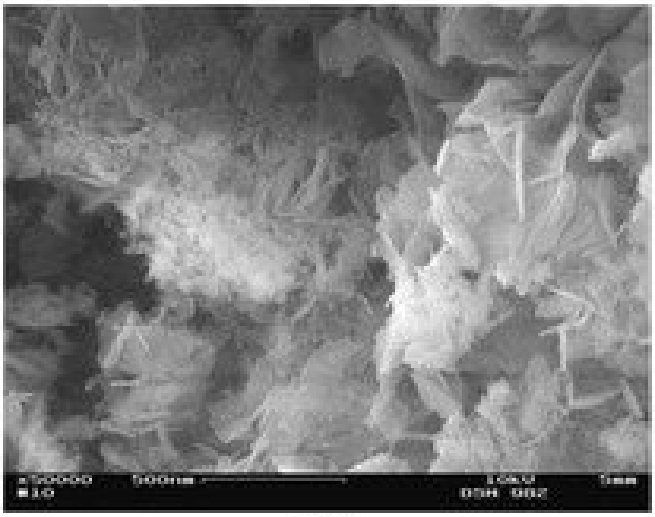


(c)

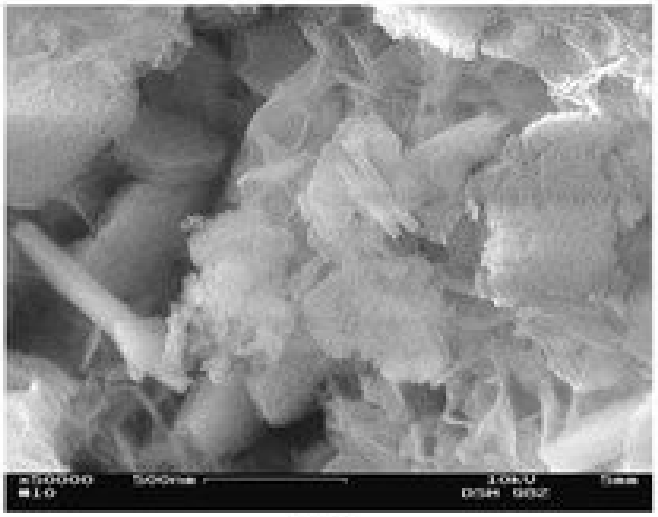

Elevate annealing temperature
Increase annealing time

(d)

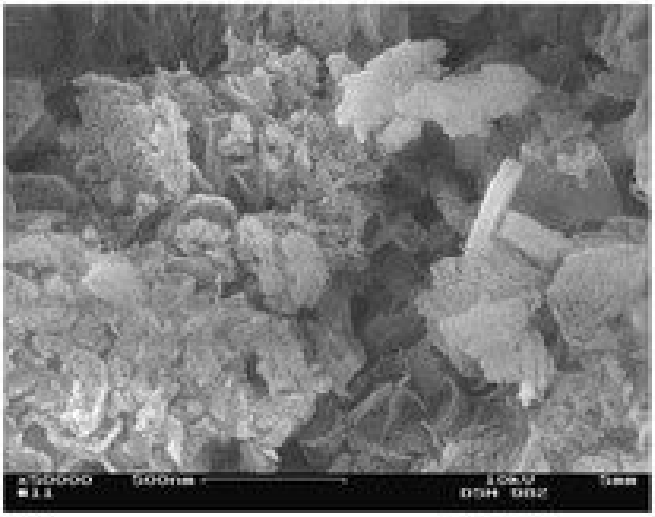

Cu-SSZ-13(1)
Cu-SSZ-13(2)
Cu-SSZ-13(3)
Cu-SSZ-13(4)
Count / arb.u.
Length / nm
1 μm



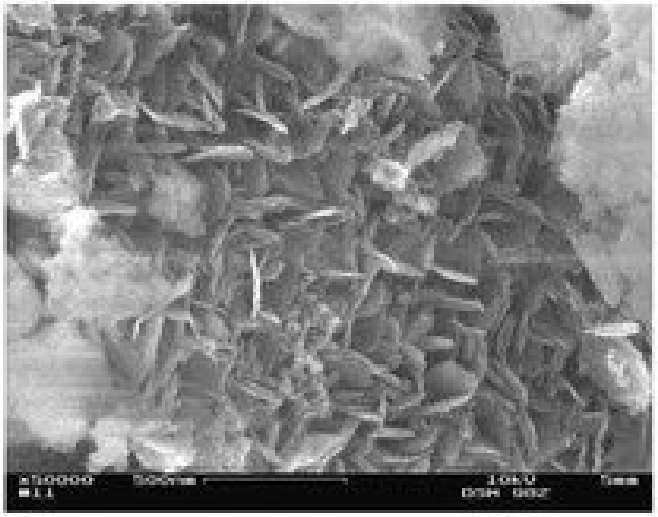
(a)



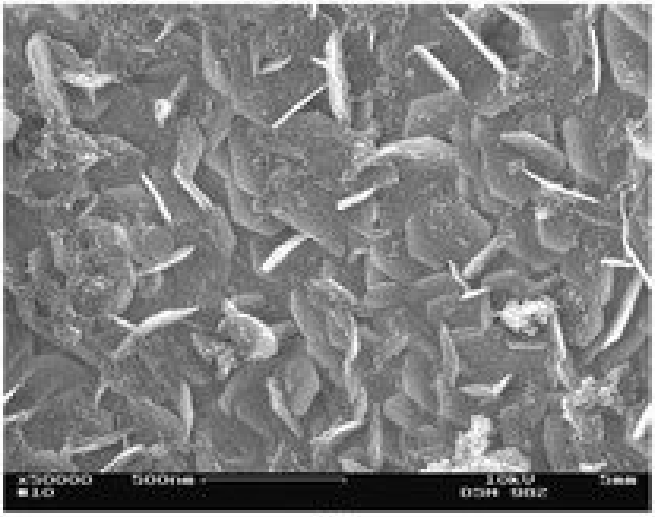
(b)



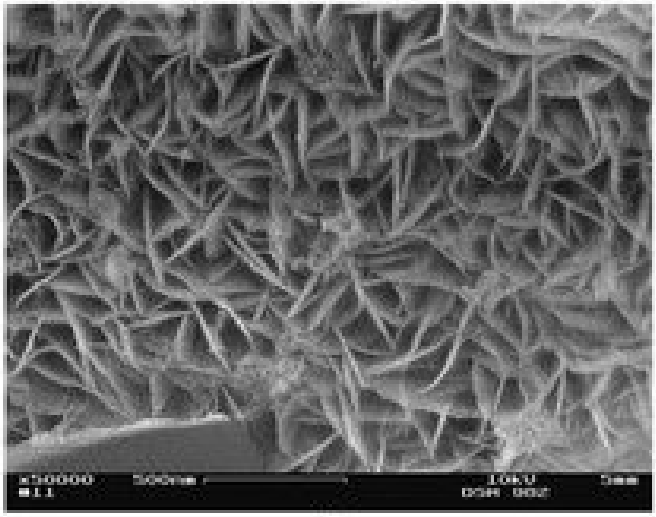
(c)



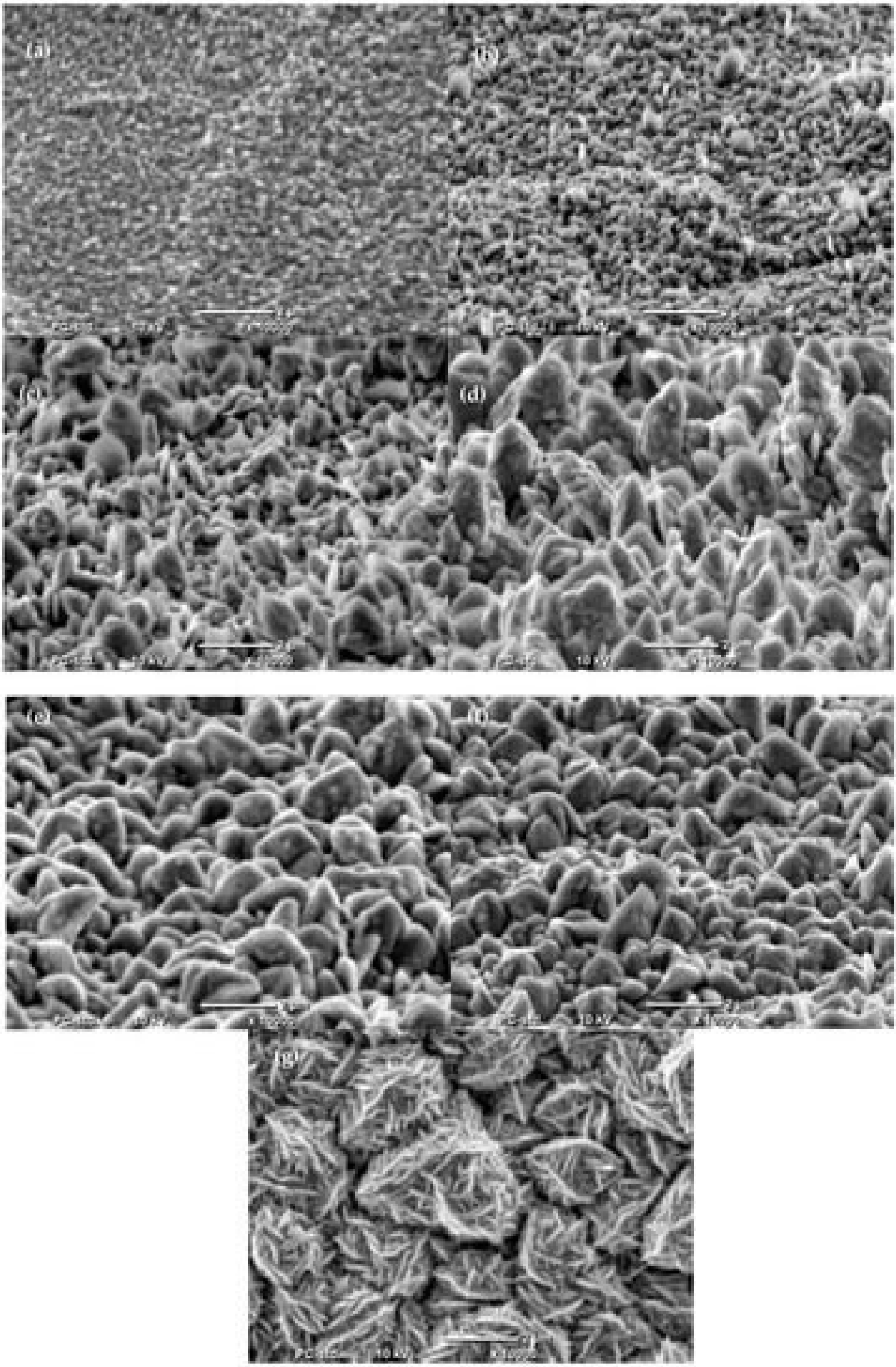
(d)

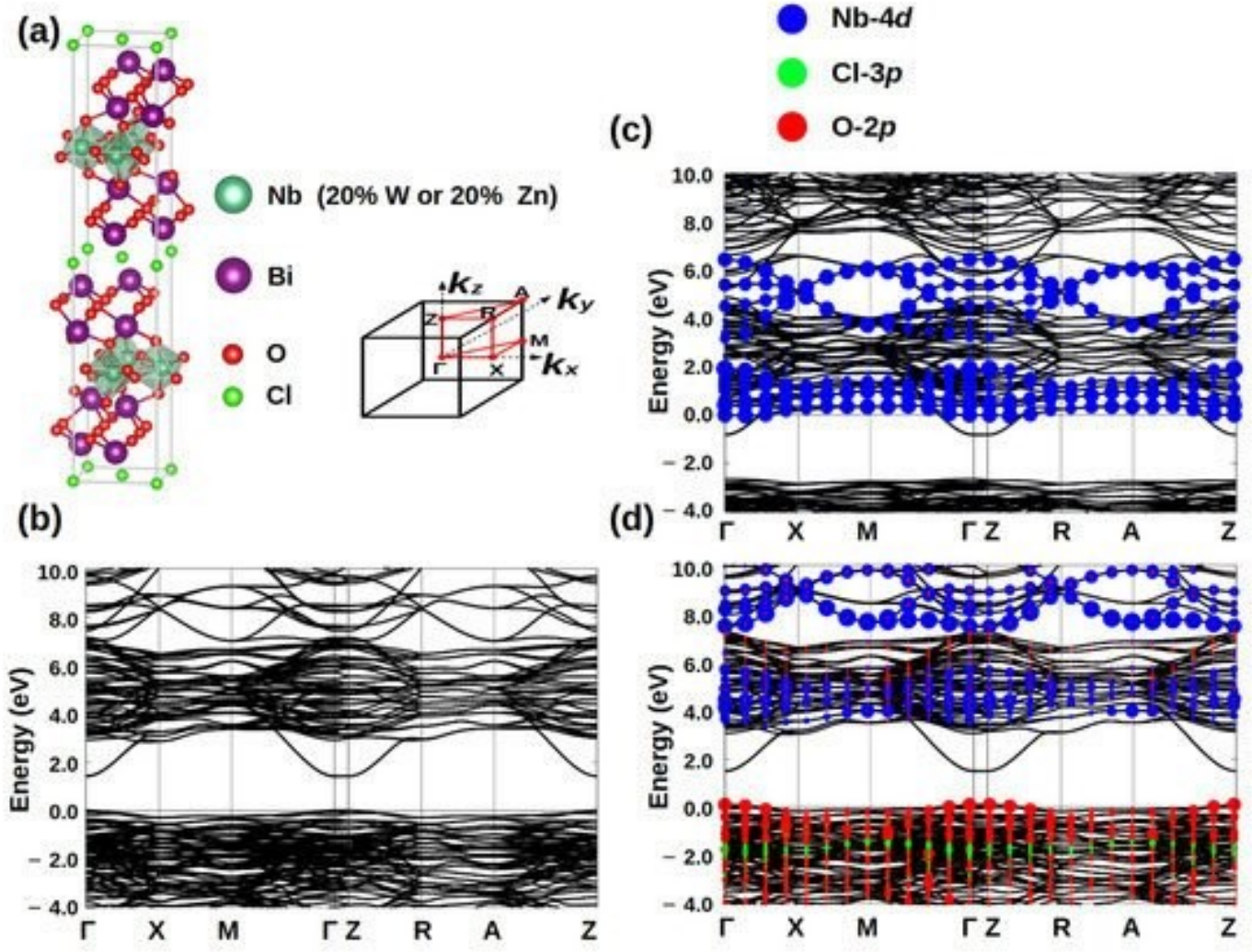


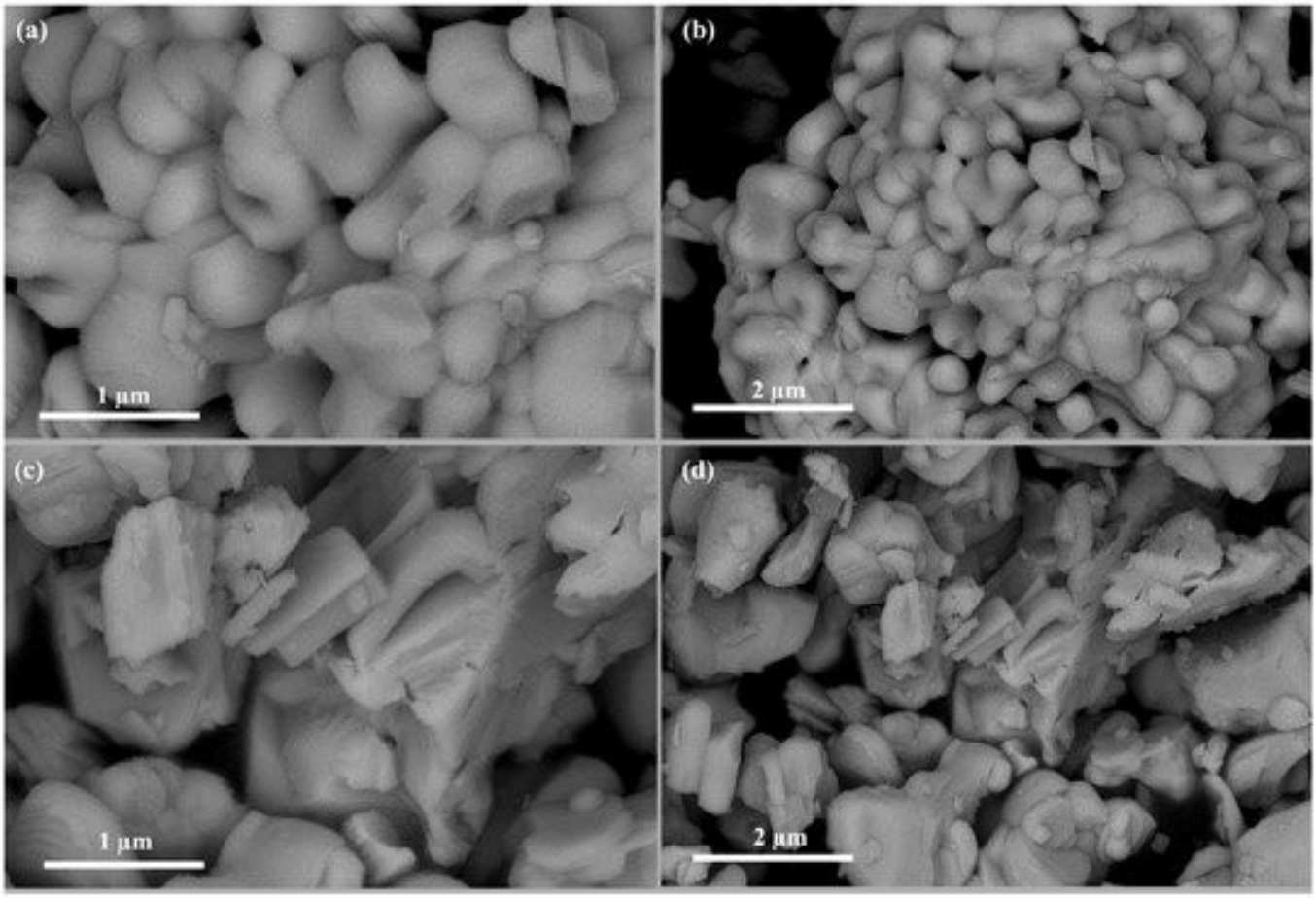
(e)

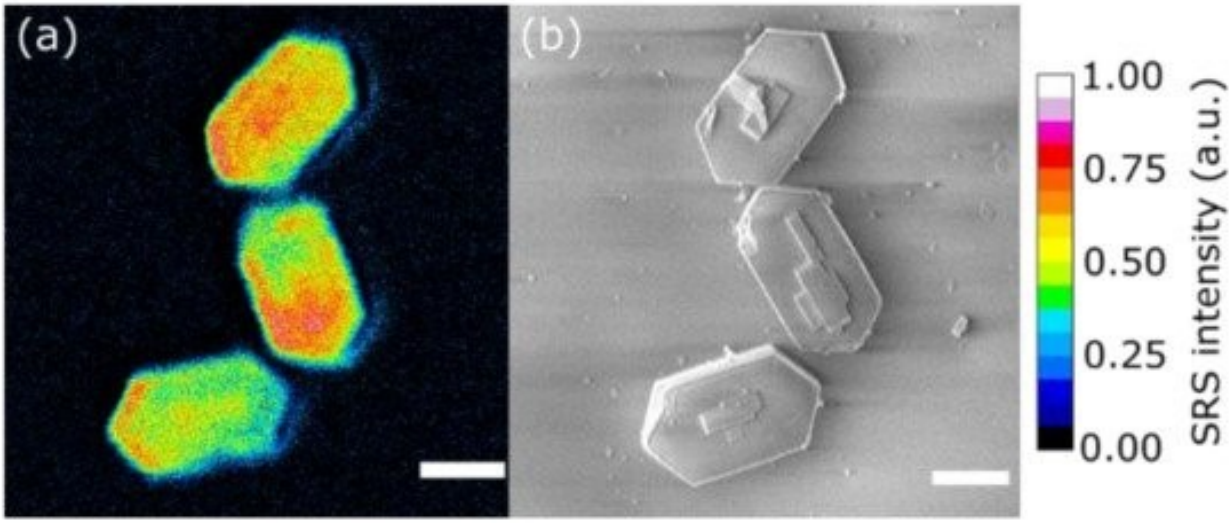


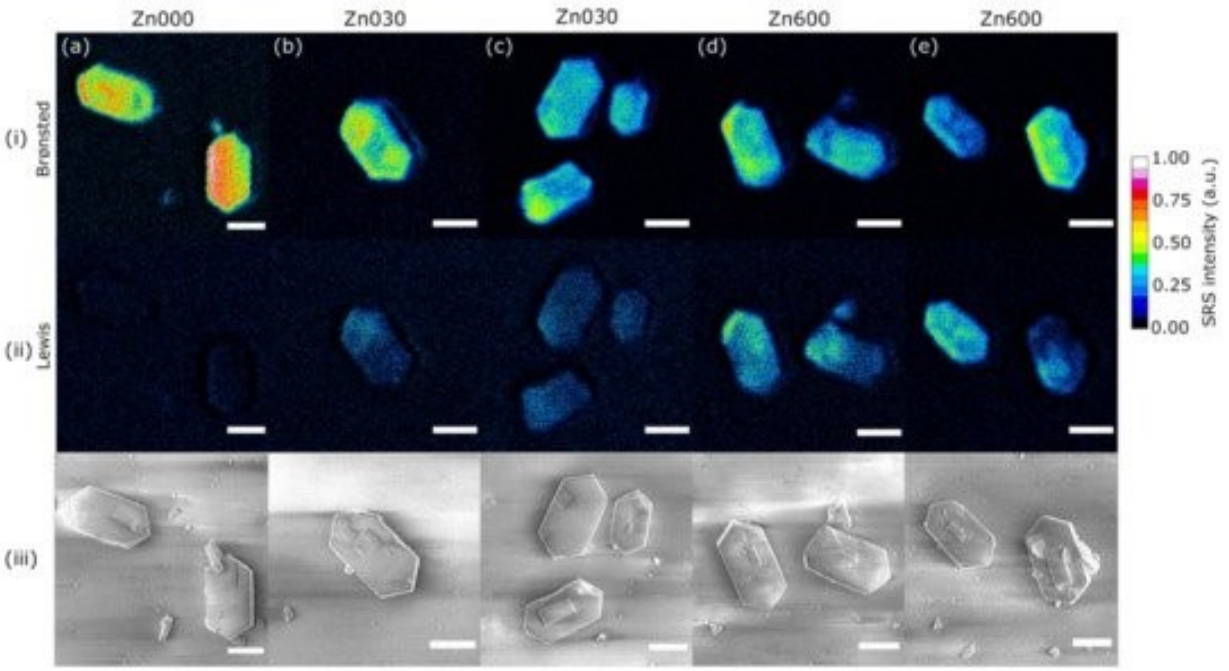
(f)

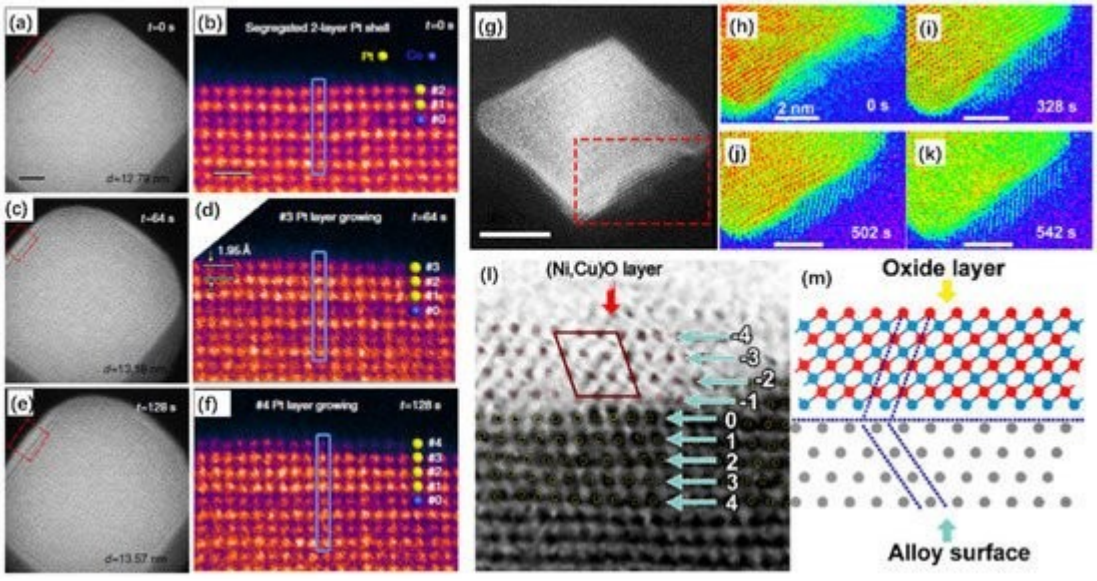

(a)
(b)
(c)
(d)
(e)
(f)
(g)

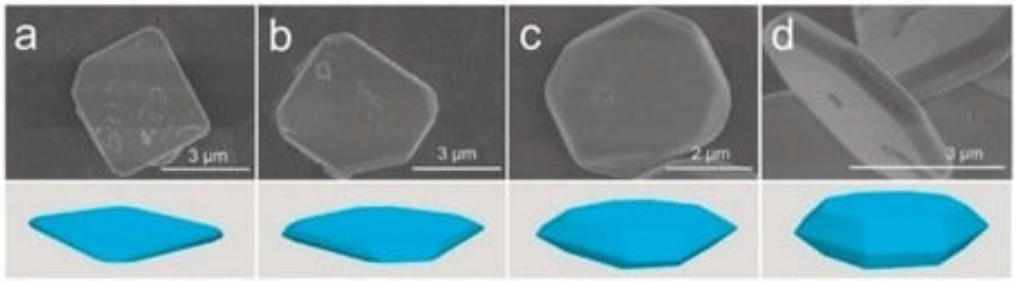

(a)
Nb (20% W or 20% Zn)
Bi
O
Cl
k_z
k_y
k_x
Z
R
A
M
Γ
X
(b)
(c)
Nb-4d
Cl-3p
O-2p
(d)
Energy (eV)
10.0
8.0
6.0
4.0
2.0
0.0
− 2.0
− 4.0
Γ X M Γ Z R A Z

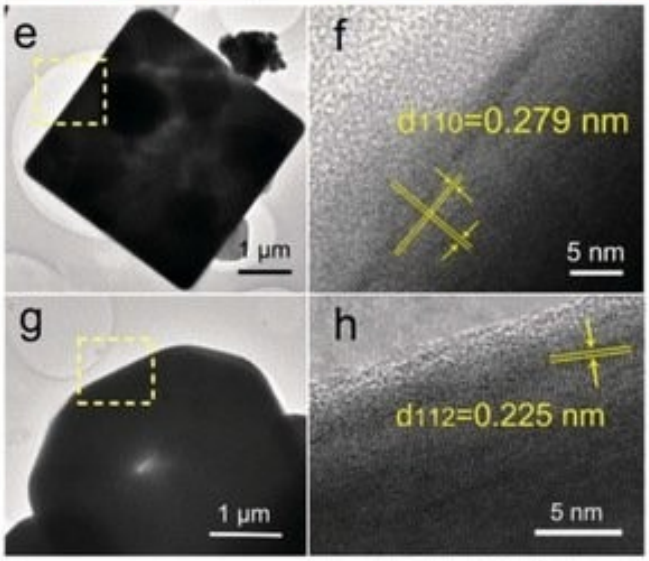

(a)
1 μm
(b)
2 μm
(c)
1 μm
(d)
2 μm

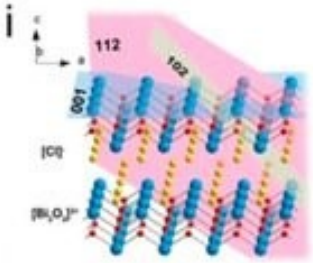

(a)
(b)
1.00
0.75
0.50
0.25
0.00
SRS intensity (a.u.)

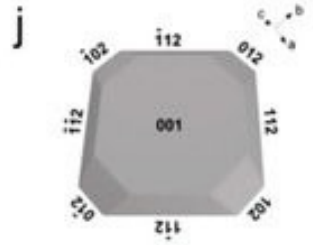

Zn000
Zn030
Zn030
Zn600
Zn600
(a)
(b)
(c)
(d)
(e)
(i) Brønsted
(ii) Lewis
(iii)
1.00
0.75
0.50
0.25
0.00
SRS intensity (a.u.)

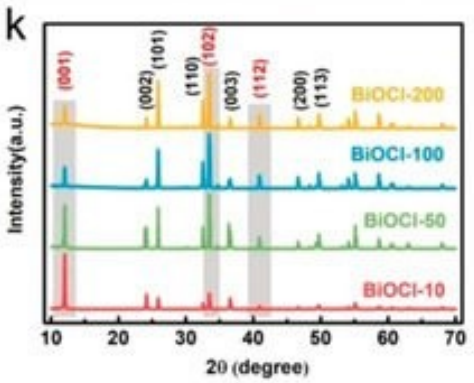

(a)
(b)
Segregated 2-layer Pt shell
(c)
(d)
#3 Pt layer growing
1.96 Å
(e)
(f)
#4 Pt layer growing
(g)
(h)
(i)
2 nm
0 s
328 s
(j)
(k)
502 s
542 s
(l)
(Ni,Cu)O layer
-4
-3
-2
-1
0
1
2
3
4
(m)
Oxide layer
Alloy surface

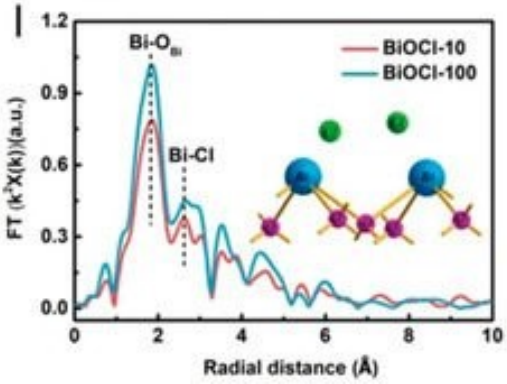

a
b
c
d
3 μm
3 μm
2 μm
3 μm

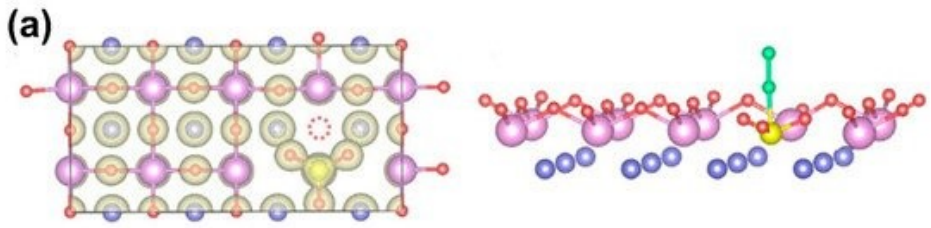

e
f
d110=0.279 nm
1 μm
5 nm
g
h
d112=0.225 nm
1 μm
5 nm


i
112
102
001
[Cs]

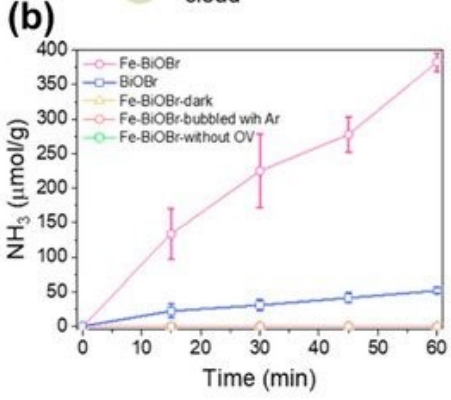

j
112
012
102
001
112
102
012
112

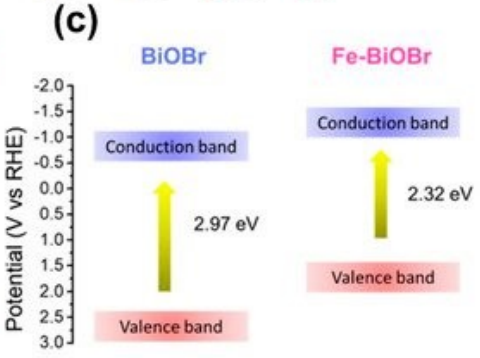

k
Intensity(a.u.)
(001)
(002)
(101)
(110)
(102)
(003)
(112)
(200)
(113)
BiOCl-200
BiOCl-100
BiOCl-50
BiOCl-10
10
20
30
40
50
60
70
2θ (degree)

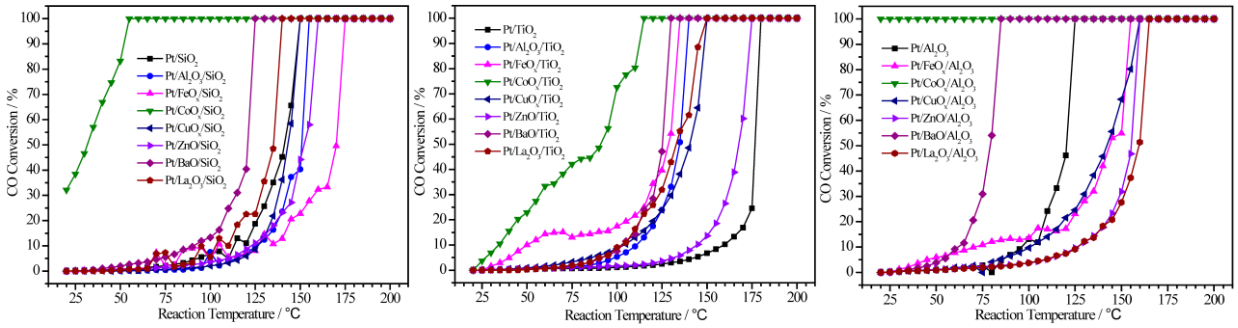

l
FT (k³X(k))(a.u.)
Bi-O
Bi-Cl
BiOCl-10
BiOCl-100
1.2
0.9
0.6
0.3
0.0
0
2
4
6
8
10
Radial distance (Å)

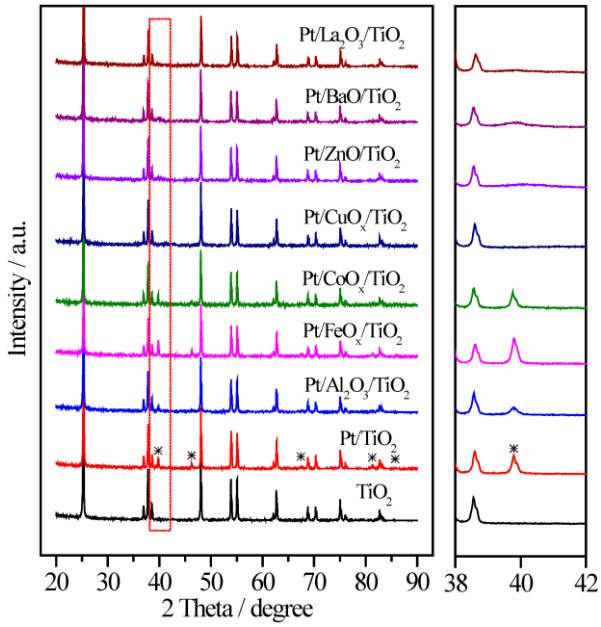

(a)

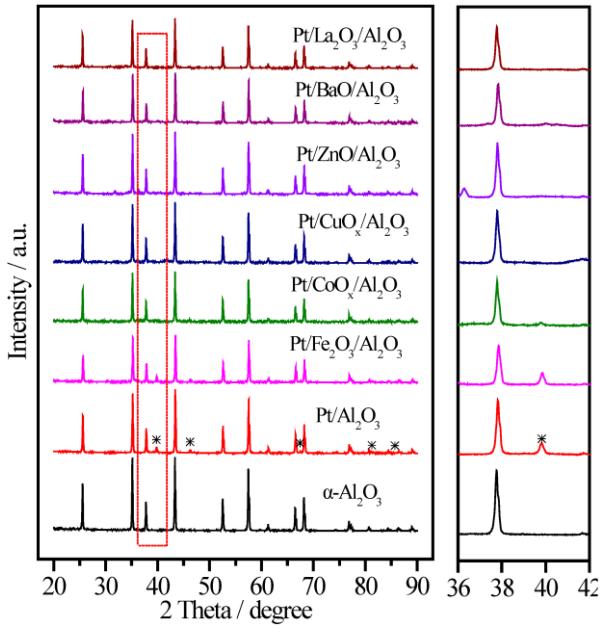
electron cloud
Bi
Fe
Br
O
OV
N

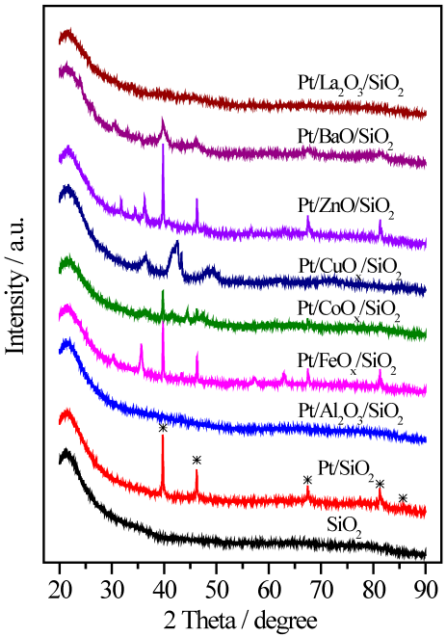

(b)
Fe-BiOBr
BiOBr
Fe-BiOBr-dark
Fe-BiOBr-bubbled wih Ar
Fe-BiOBr-without OV
NH3 (μmol/g)
400
350
300
250
200
150
100
50
0
0
10
20
30
40
50
60
Time (min)

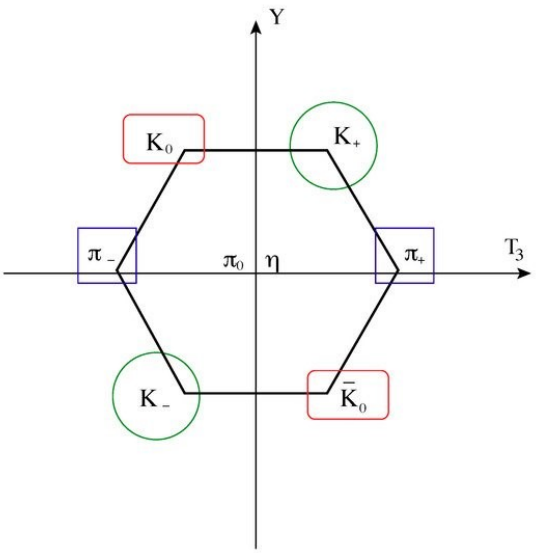

(c)
BiOBr
Fe-BiOBr
Conduction band
2.97 eV
Valence band
Conduction band
2.32 eV
Valence band
Potential (V vs RHE)
-2.0
-1.5
-1.0
-0.5
0.0
0.5
1.0
1.5
2.0
2.5
3.0

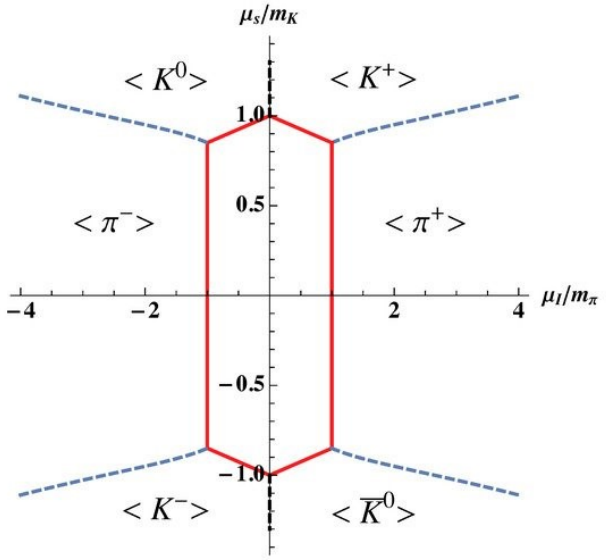

CO Conversion / %
Reaction Temperature / °C
Pt/SiO2
Pt/Al2O3/SiO2
Pt/FeOx/SiO2
Pt/CoOx/SiO2
Pt/CuOx/SiO2
Pt/ZnO/SiO2
Pt/BaO/SiO2
Pt/La2O3/SiO2
Pt/TiO2
Pt/Al2O3/TiO2
Pt/FeOx/TiO2
Pt/CoOx/TiO2
Pt/CuOx/TiO2
Pt/ZnO/TiO2
Pt/BaO/TiO2
Pt/La2O3/TiO2
Pt/Al2O3
Pt/FeOx/Al2O3
Pt/CoOx/Al2O3
Pt/CuOx/Al2O3
Pt/ZnO/Al2O3
Pt/BaO/Al2O3
Pt/La2O3/Al2O3

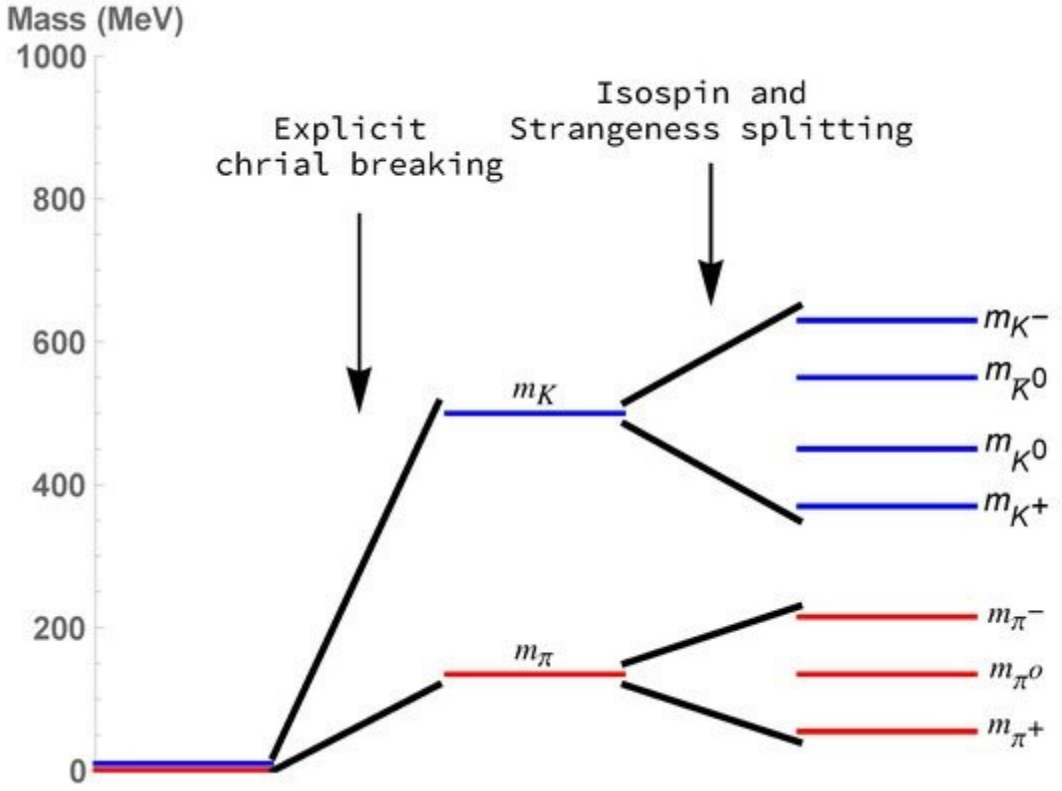

Intensity / a.u.
2 Theta / degree
Pt/La2O3/TiO2
Pt/BaO/TiO2
Pt/ZnO/TiO2
Pt/CuOx/TiO2
Pt/CoOx/TiO2
Pt/FeOx/TiO2
Pt/Al2O3/TiO2
Pt/TiO2
TiO2

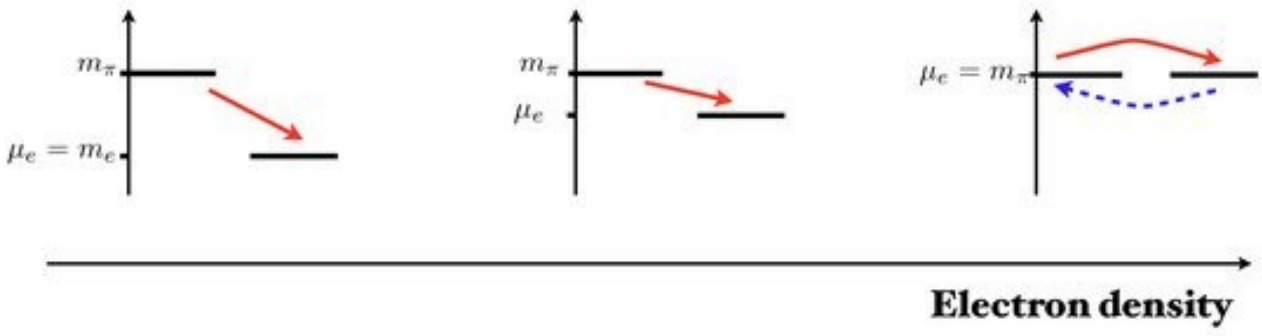

Intensity / a.u.
2 Theta / degree
Pt/La2O3/Al2O3
Pt/BaO/Al2O3
Pt/ZnO/Al2O3
Pt/CuOx/Al2O3
Pt/CoOx/Al2O3
Pt/Fe2O3/Al2O3
Pt/Al2O3
α-Al2O3

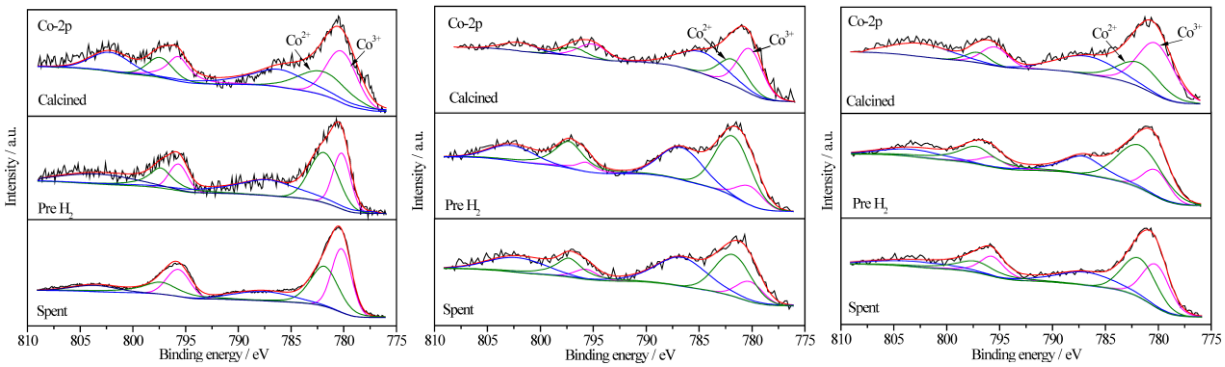

Intensity / a.u.
2 Theta / degree
Pt/La2O3/SiO2
Pt/BaO/SiO2
Pt/ZnO/SiO2
Pt/CuO /SiO2
Pt/CoO /SiO2
Pt/FeOx/SiO2
Pt/Al2O3/SiO2
Pt/SiO2
SiO2

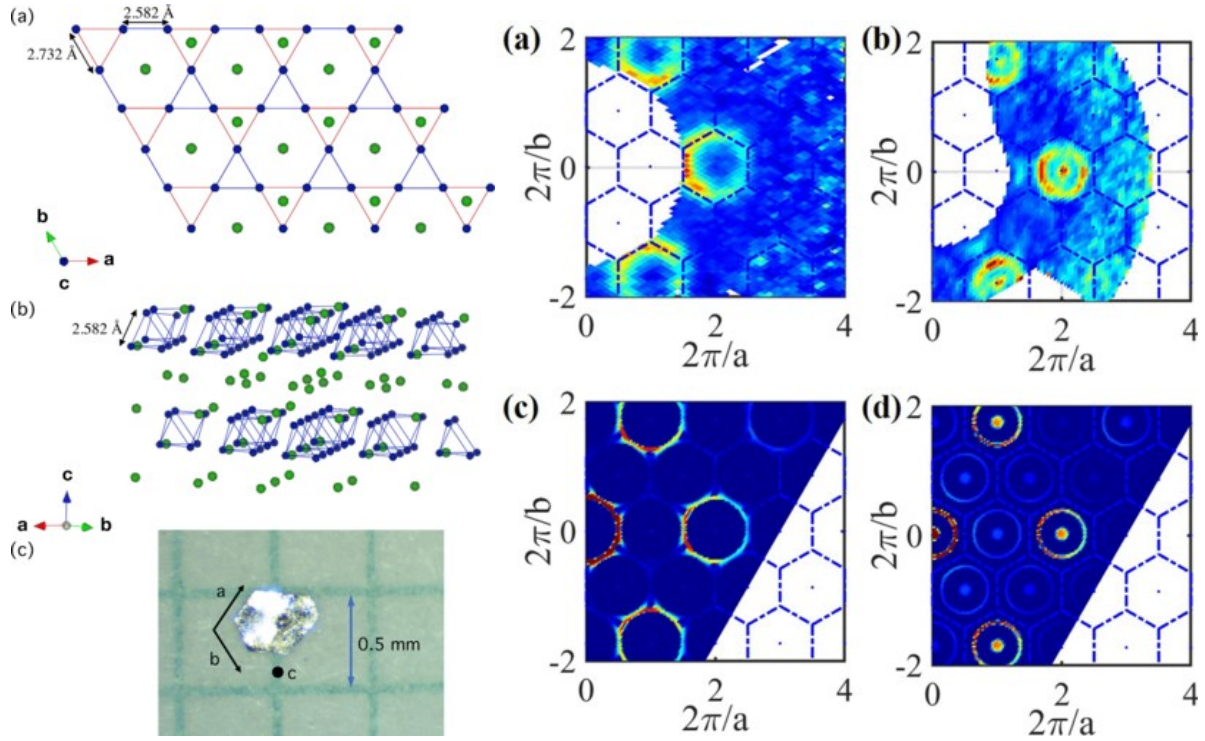

Y
K0
K+
π -
π0
η
π+
T3
K -
K̄0

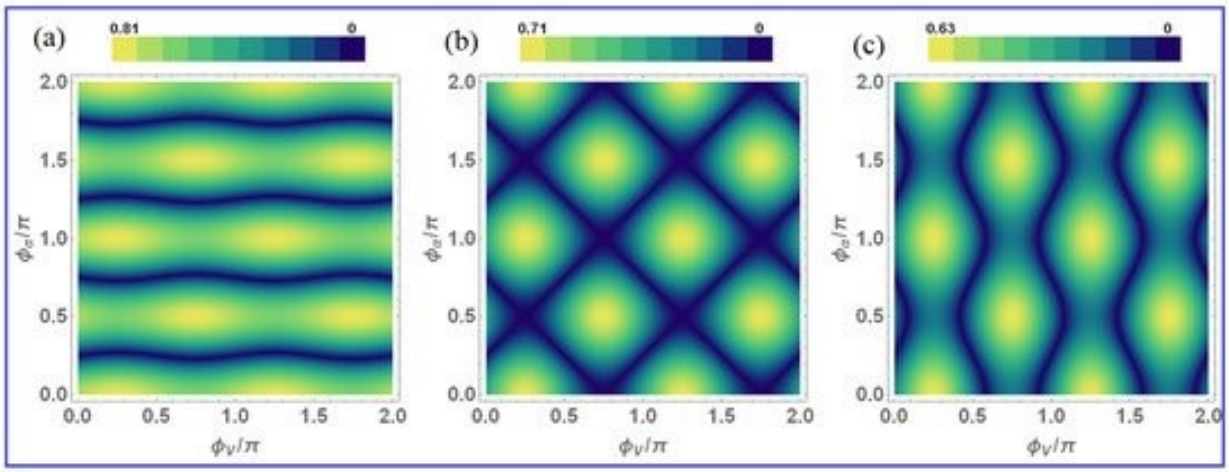

μs/mK
< K0 >
< K+ >
1.0
0.5
< π− >
< π+ >
μI/mπ
−4
−2
2
4
−0.5
−1.0
< K− >
< K̄0 >

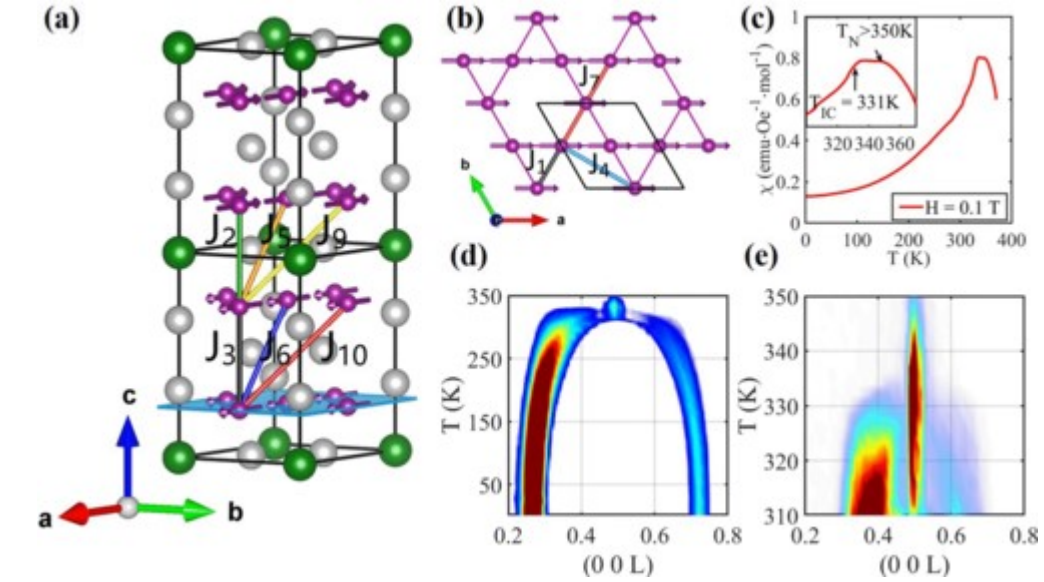

Mass (MeV)
1000
800
600
400
200
0
Explicit
chrial breaking
Isospin and
Strangeness splitting
mK
mK−
mK0
mK0
mK+
mπ
mπ−
mπo
mπ+

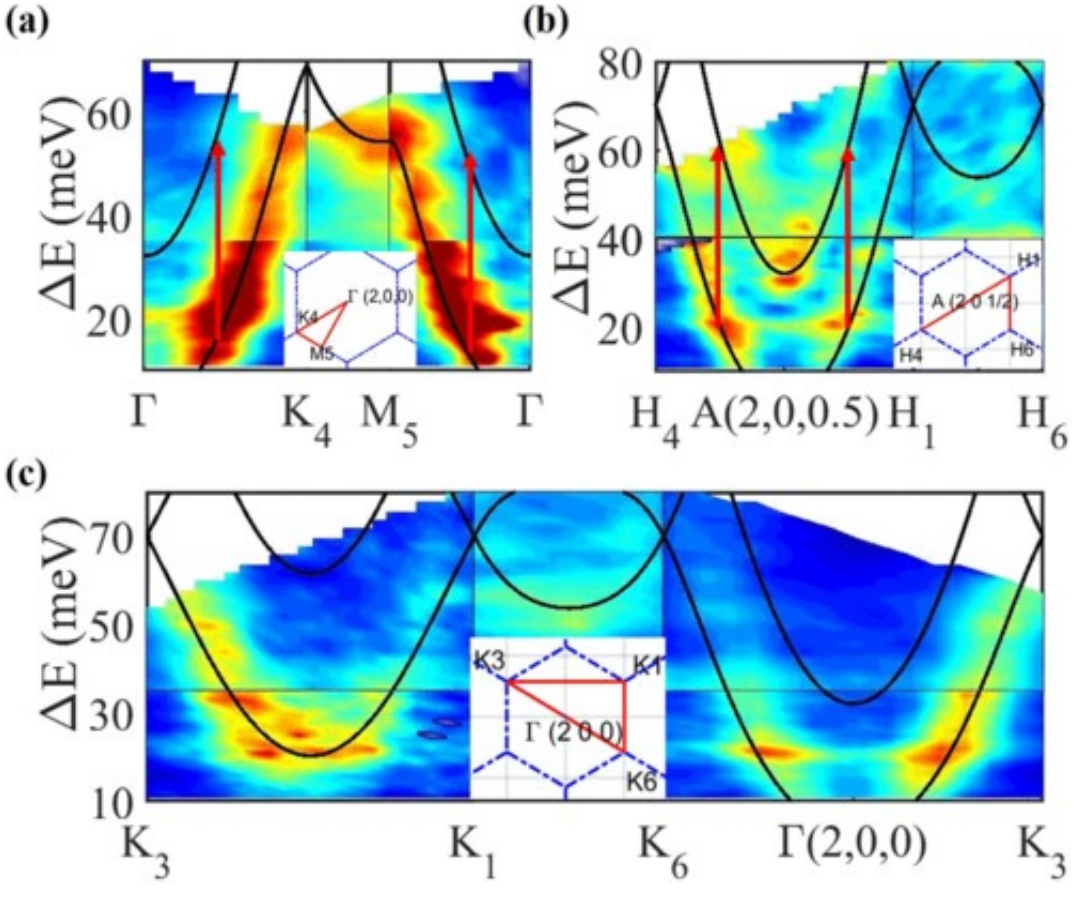

mπ
μe = me
mπ
μe
μe = mπ
Electron density

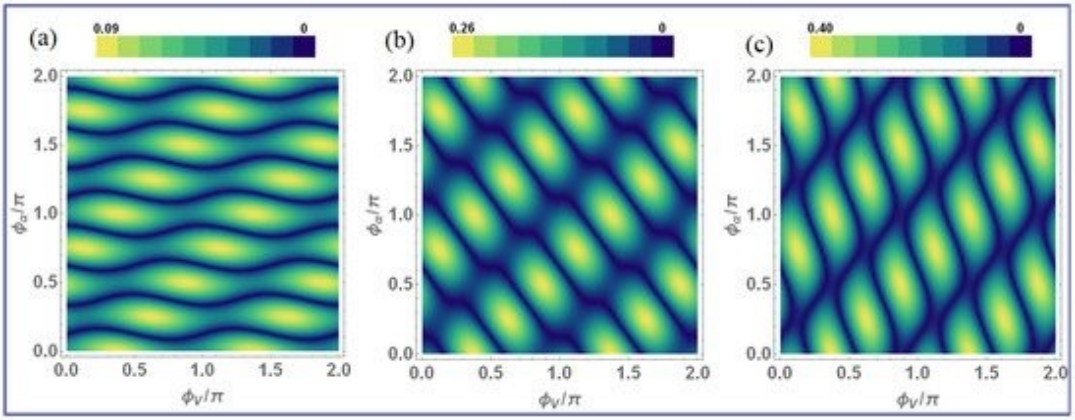

Co-2p
Co2+
Co3+
Calcined
Pre H2
Spent
Intensity / a.u.
Binding energy / eV
810 805 800 795 790 785 780 775

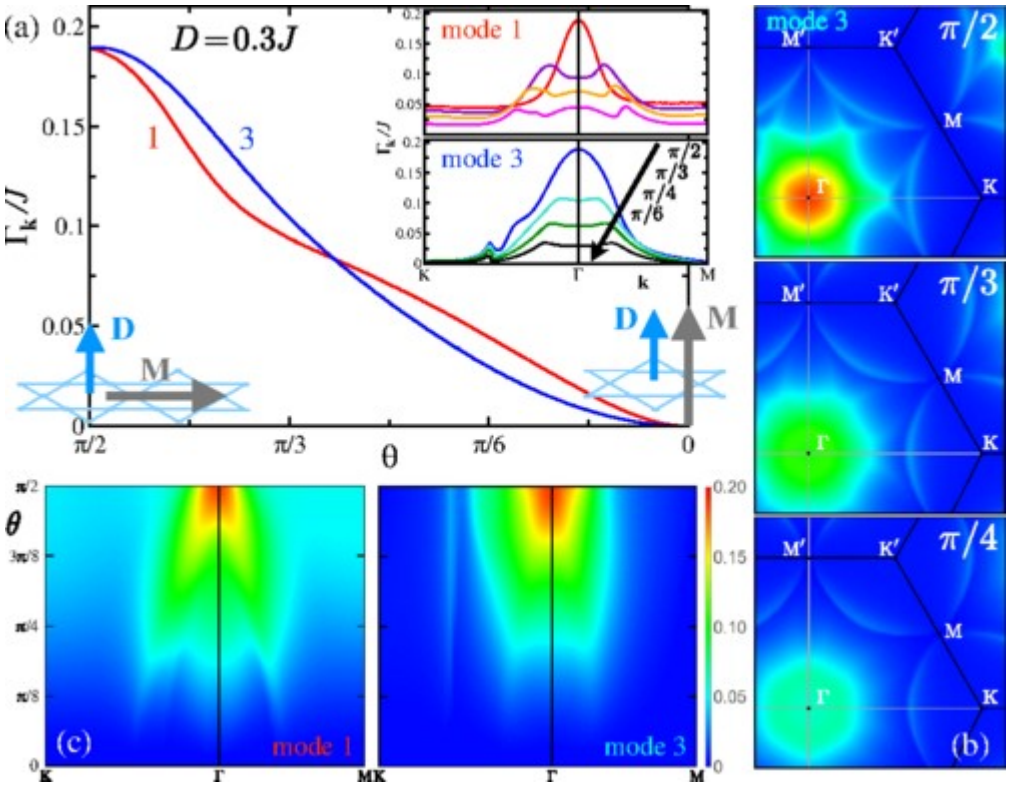

(a)
2.582 Å
2.732 Å
b
a
c
(b)
2.582 Å
c
a
b
(c)
a
b
c
0.5 mm
(a)
(b)
(c)
(d)
2π/b
2π/a
2
0
-2
0
2
4

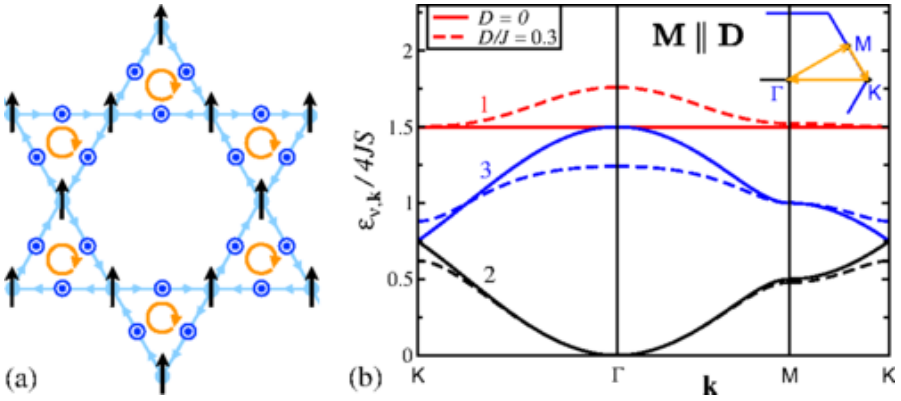

(a)
0.81
0
(b)
0.71
0
(c)
0.63
0
ϕ_σ/π
ϕ_V/π
0.0
0.5
1.0
1.5
2.0

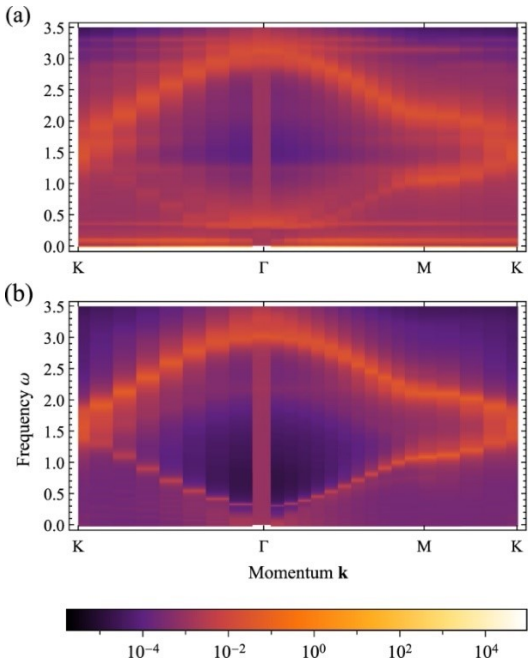

(a)
J2
J5
J9
J3
J6
J10
c
a
b
(b)
J7
J1
J4
b
c
a
(c)
T_N>350K
T_BC = 331K
320 340 360
χ (emu-Oe⁻¹-mol⁻¹)
H = 0.1 T
T (K)
(d)
T (K)
(0 0 L)
(e)
T (K)
(0 0 L)

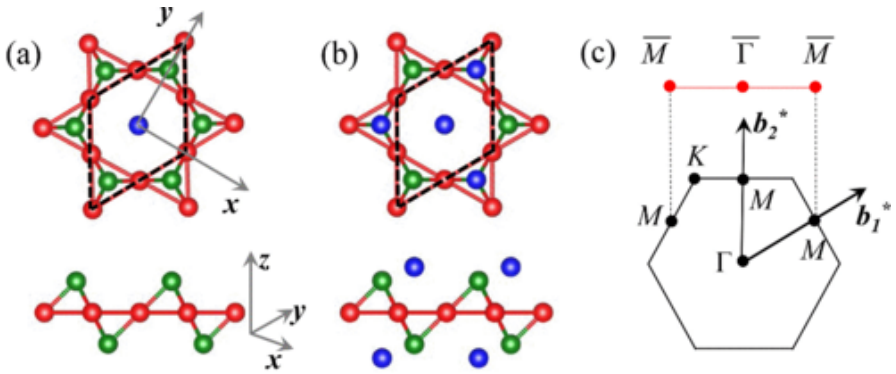

(a)
ΔE (meV)
Γ (2,0,0)
K4
M5
Γ
K4
M5
Γ
(b)
ΔE (meV)
H1
A (2 0 1/2)
H4
H6
H4
A(2,0,0.5)
H1
H6
(c)
ΔE (meV)
K3
K1
Γ (2 0 0)
K6
K3
K1
K6
Γ(2,0,0)
K3

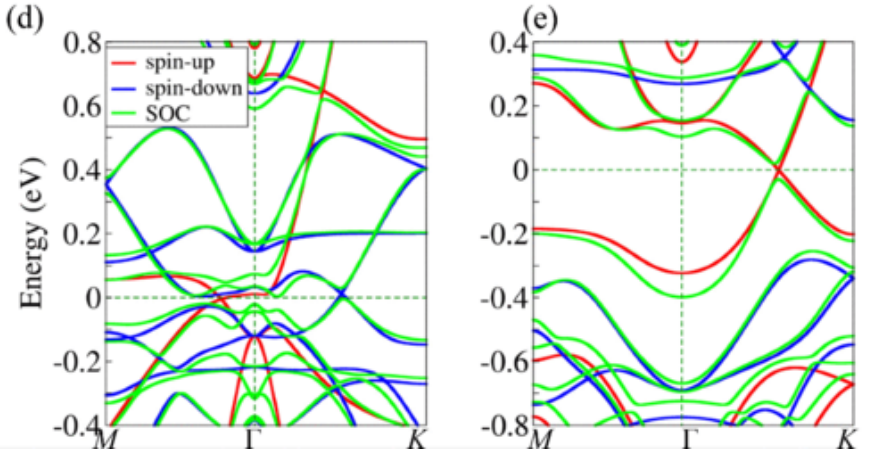

(a)
(b)
(c)
ϕ_α/π
ϕ_V/π

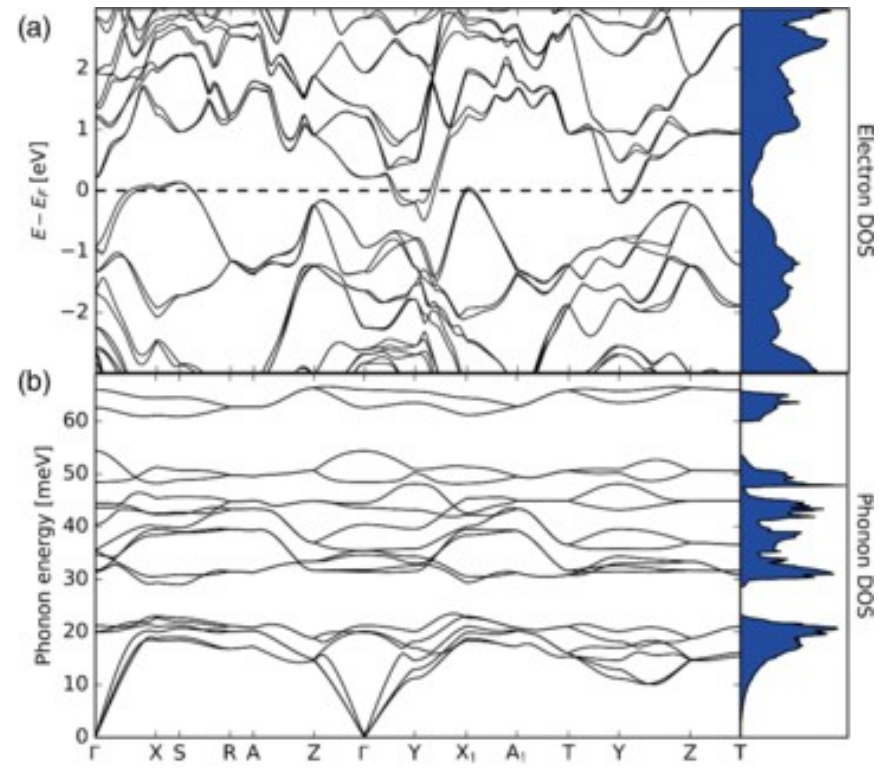

(a)
D=0.3J
mode 1
mode 3
1
3
D
M
θ
π/2
π/3
π/6
0
mode 3
π/2
π/3
π/4
(c)
mode 1
mode 3
(b)

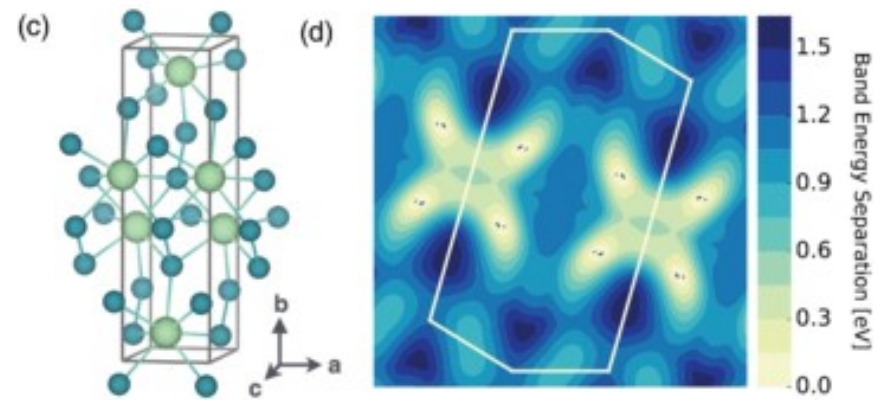

(a)
D = 0
D/J = 0.3
M ∥ D
M
Γ
K
1
2
3
(b)
K
Γ
M
K
k

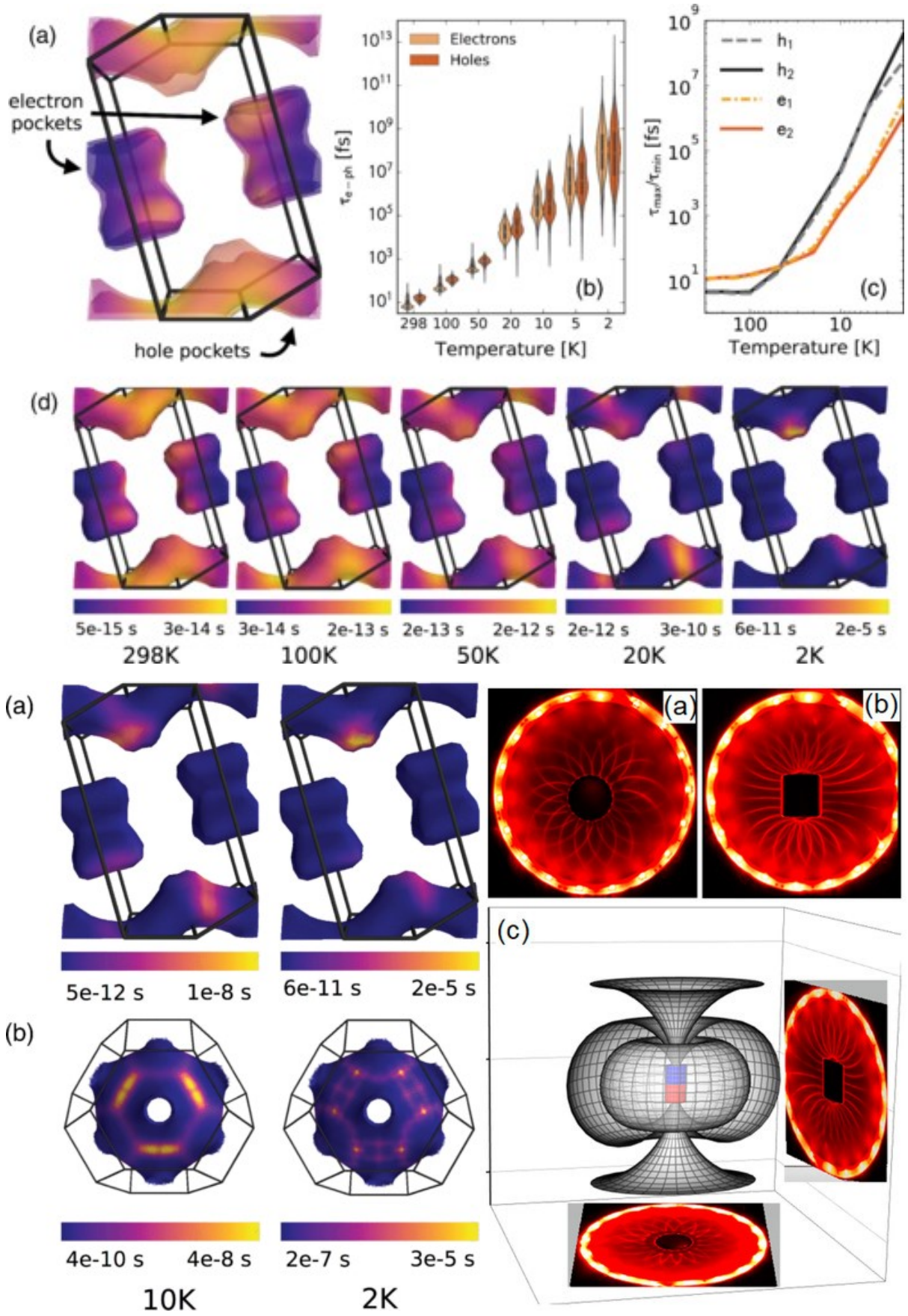

(a)
(b)
K
Γ
M
K
Frequency ω
Momentum k

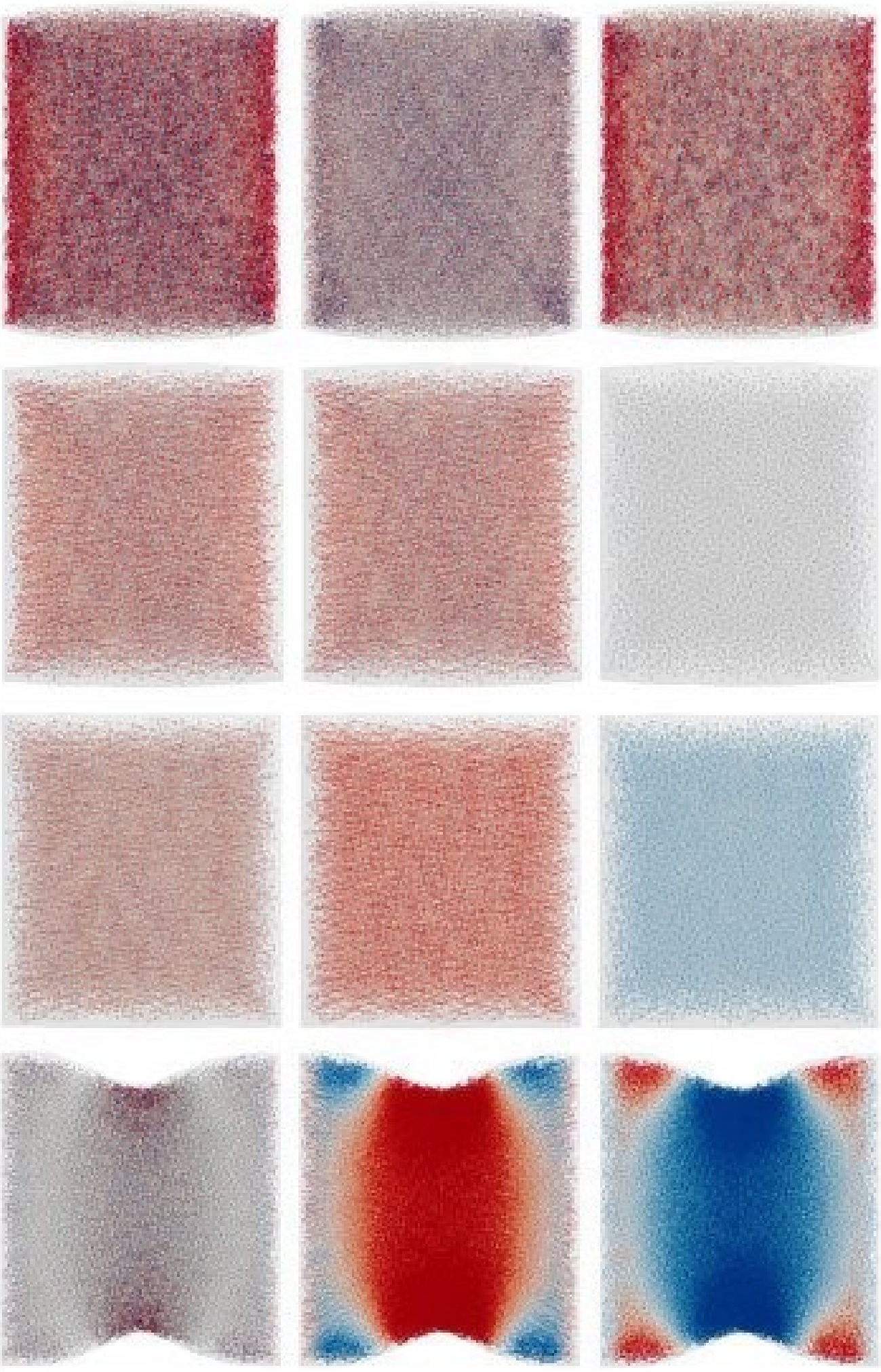

(a)
y
x
z
y
x
(b)
(c)
M̄
Γ̄
M̄
b2*
K
M
M
Γ
M
b1*

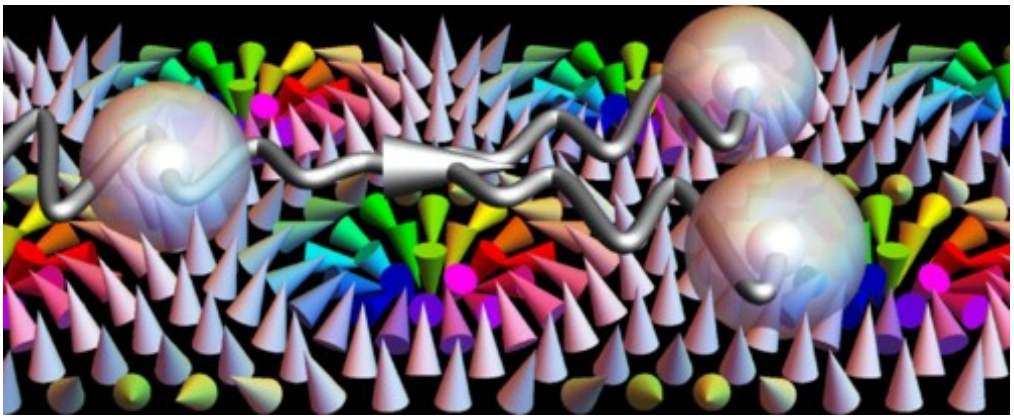

(d)
spin-up
spin-down
SOC
Energy (eV)
0.8
0.6
0.4
0.2
0
-0.2
-0.4
M
Γ
K
(e)
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
M
Γ
K

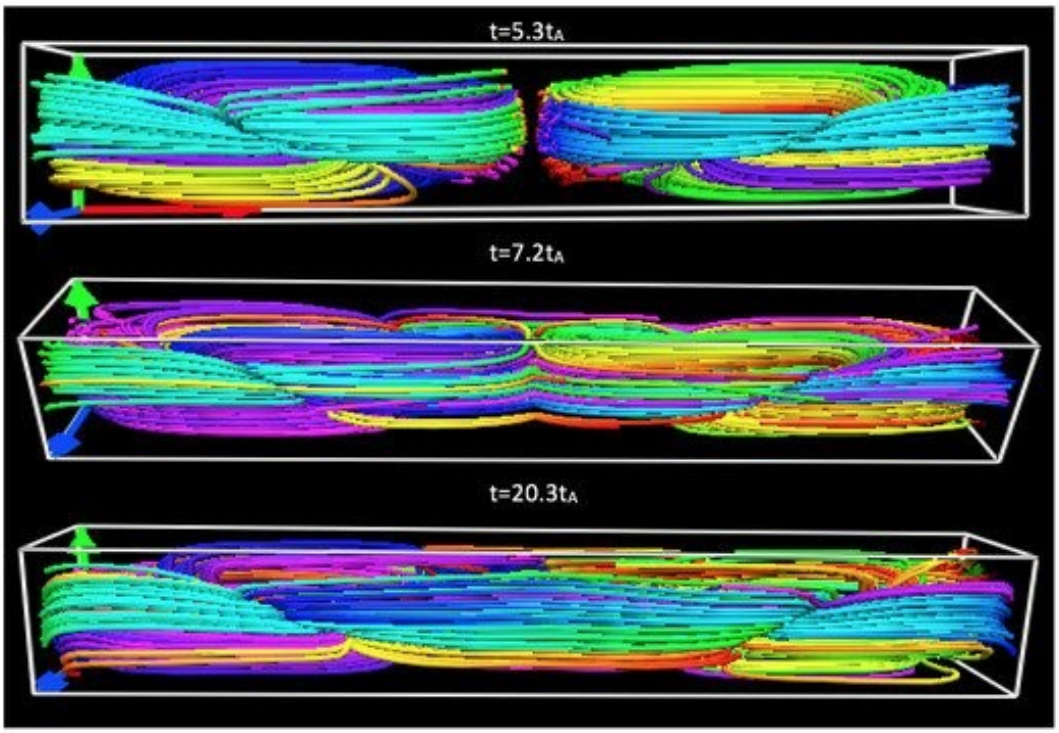

(a)
E − E_F [eV]
2
1
0
−1
−2
Electron DOS
(b)
Phonon energy [meV]
60
50
40
30
20
10
0
Γ X S R A Z Γ Y X1 A1 T Y Z T
Phonon DOS

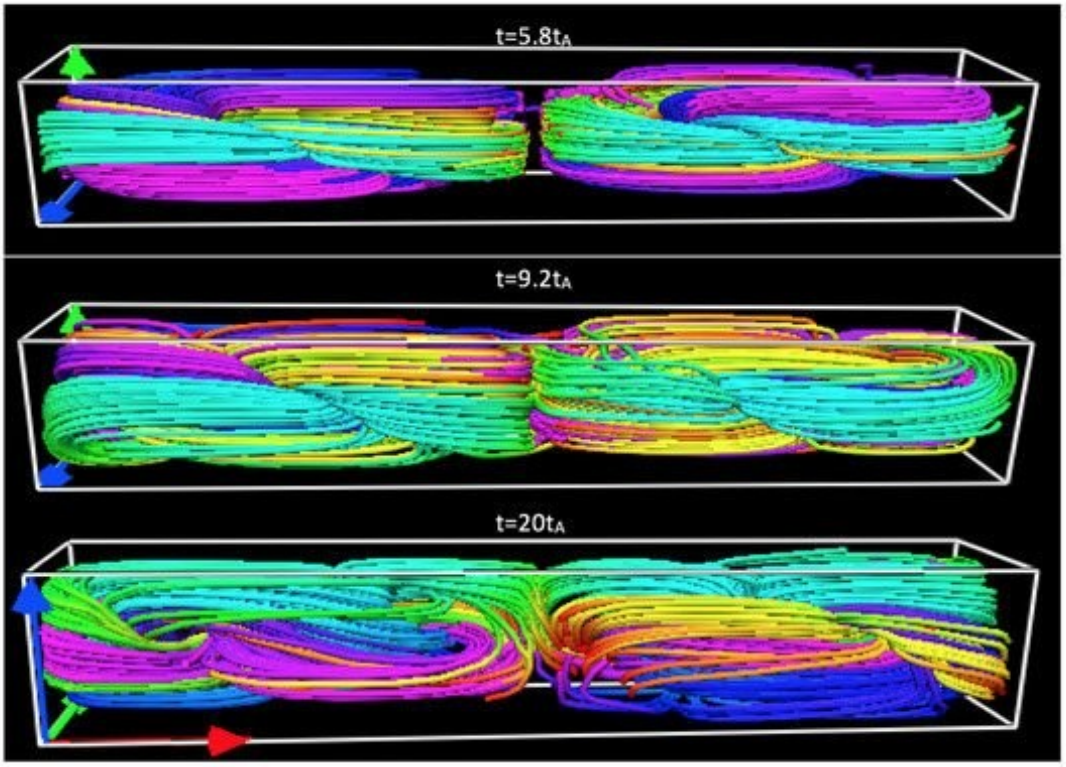

(c)
b
a
c
(d)
1.5
1.2
0.9
0.6
0.3
0.0
Band Energy Separation [eV]

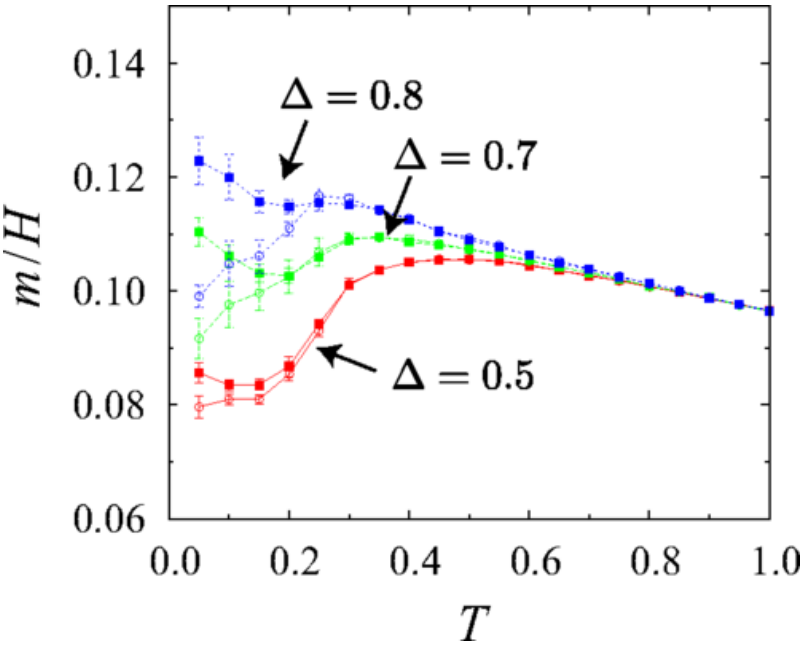

(a)
electron pockets
hole pockets
Electrons
Holes
τ_{e-ph} [fs]
Temperature [K]
(b)
τ_{max}/τ_{min} [fs]
h_1
h_2
e_1
e_2
Temperature [K]
(c)
(d)
5e-15 s
3e-14 s
298K
3e-14 s
2e-13 s
100K
2e-13 s
2e-12 s
50K
2e-12 s
3e-10 s
20K
6e-11 s
2e-5 s
2K
(a)
5e-12 s
1e-8 s
6e-11 s
2e-5 s
(b)
4e-10 s
4e-8 s
10K
2e-7 s
3e-5 s
2K
(a)
(b)
(c)

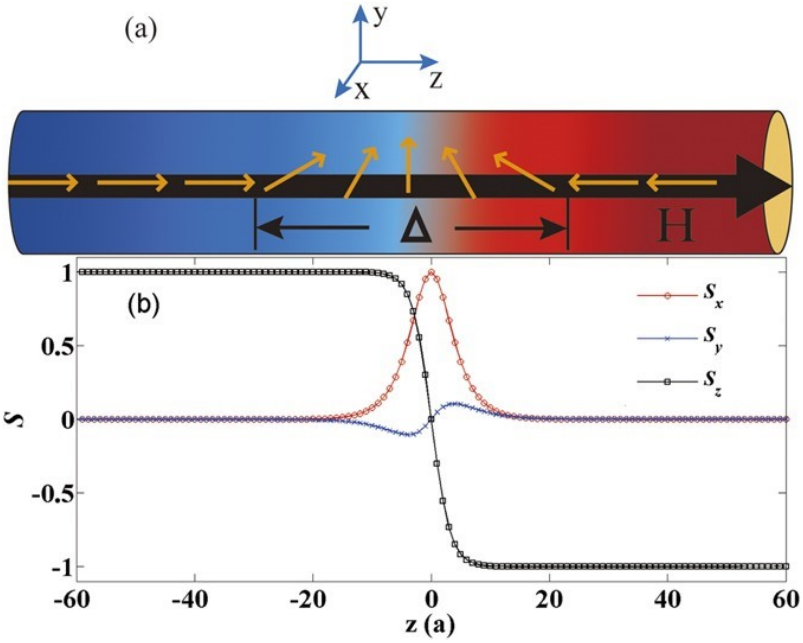


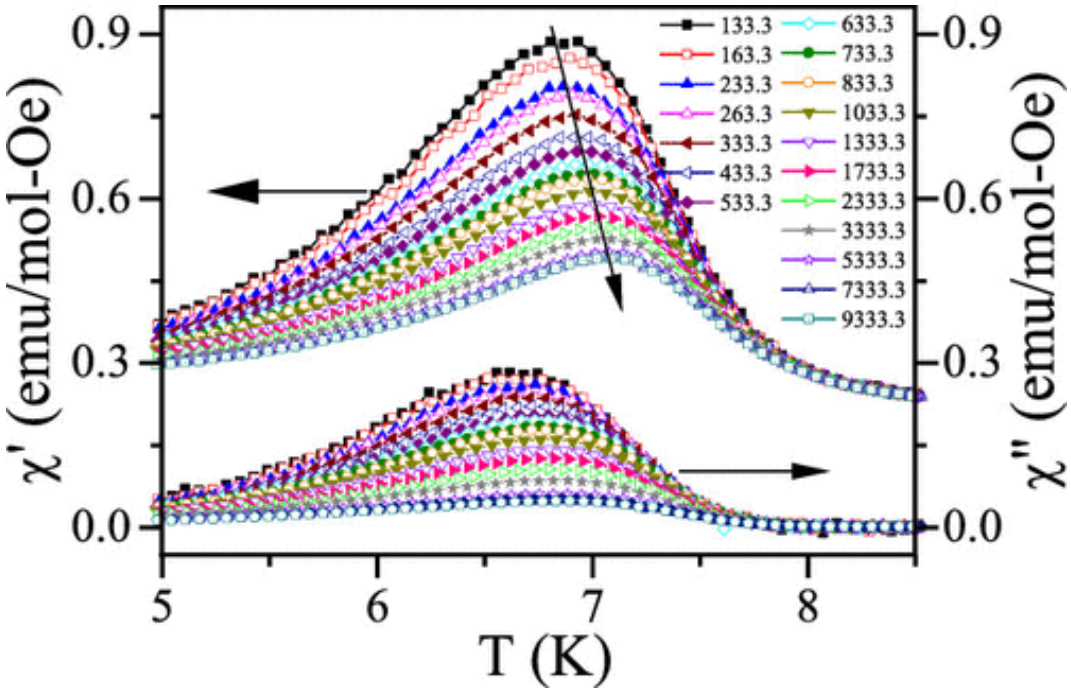


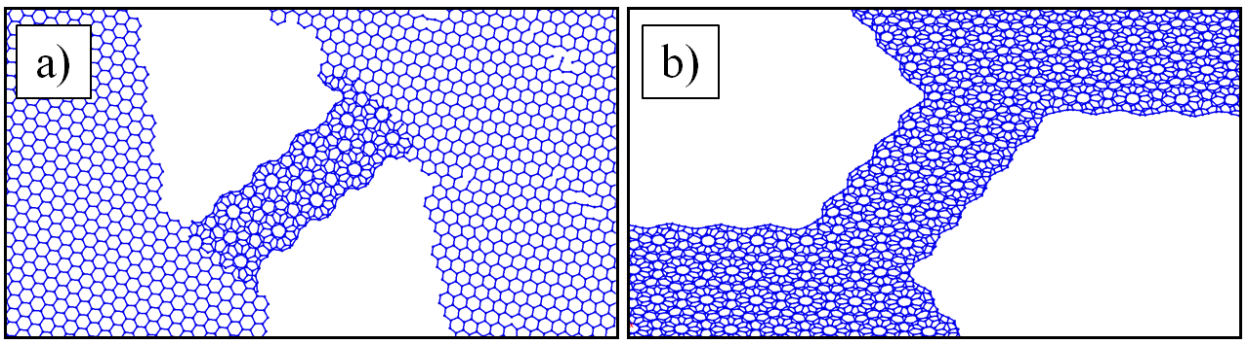

t=5.3tA
t=7.2tA
t=20.3tA


t=5.8tA
t=9.2tA
t=20tA

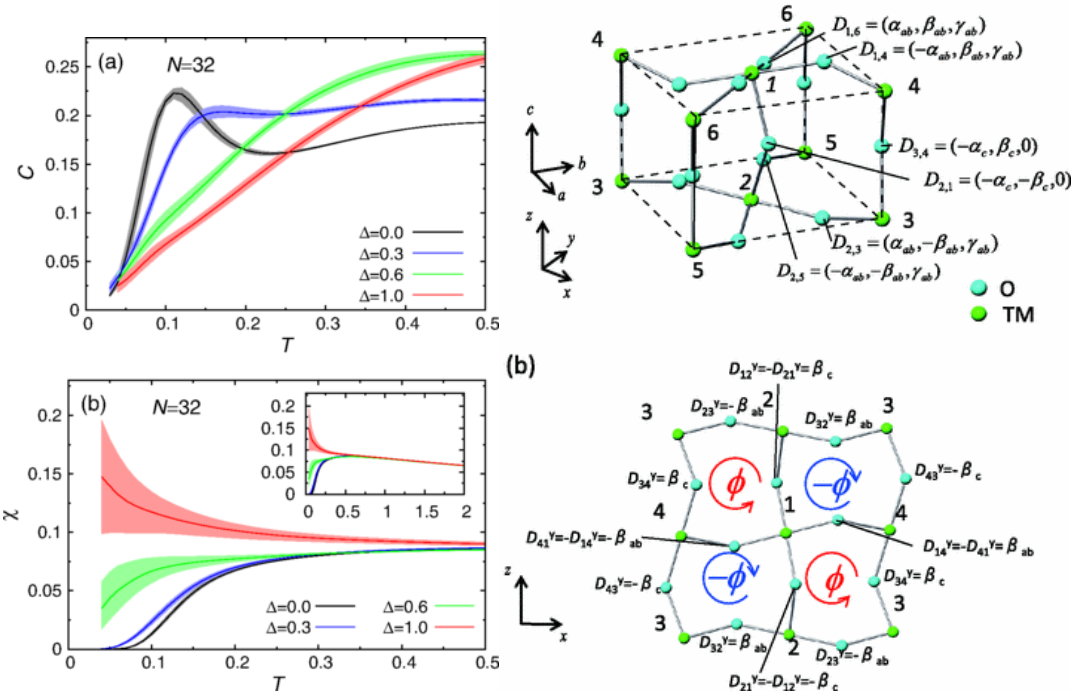

0.14
0.12
0.10
0.08
0.06
m/H
Δ = 0.8
Δ = 0.7
Δ = 0.5
0.0
0.2
0.4
0.6
0.8
1.0
T


(a)
y
x
z
Δ
H
(b)
1
0.5
0
-0.5
-1
S
S_x
S_y
S_z
-60
-40
-20
0
20
40
60
z (a)

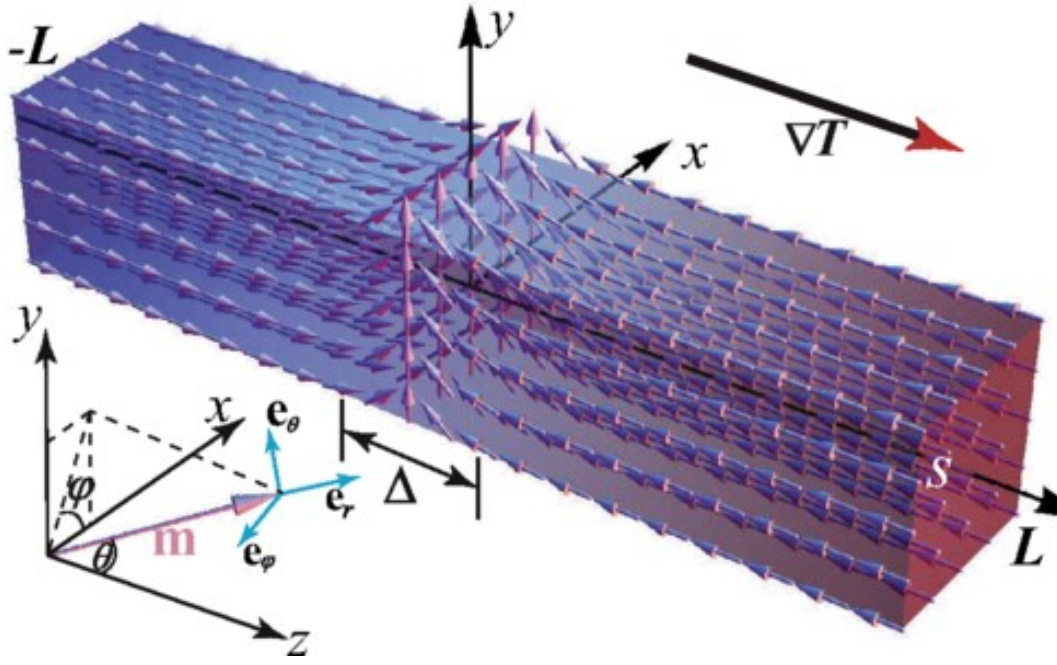

0.9
0.6
0.3
0.0
χ' (emu/mol-Oe)
χ'' (emu/mol-Oe)
133.3
163.3
233.3
263.3
333.3
433.3
533.3
633.3
733.3
833.3
1033.3
1333.3
1733.3
2333.3
3333.3
5333.3
7333.3
9333.3
5
6
7
8
T (K)

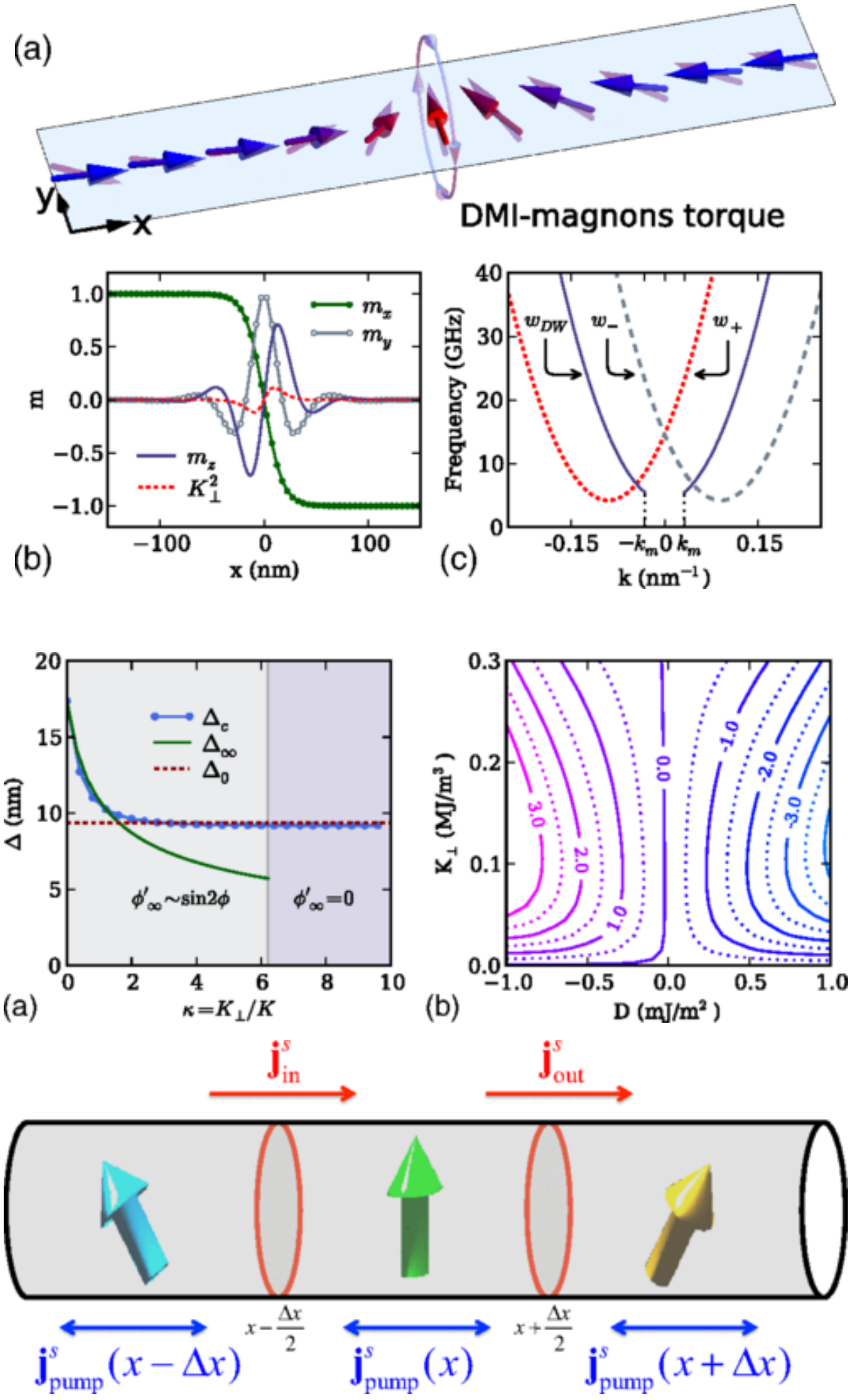

a)
b)

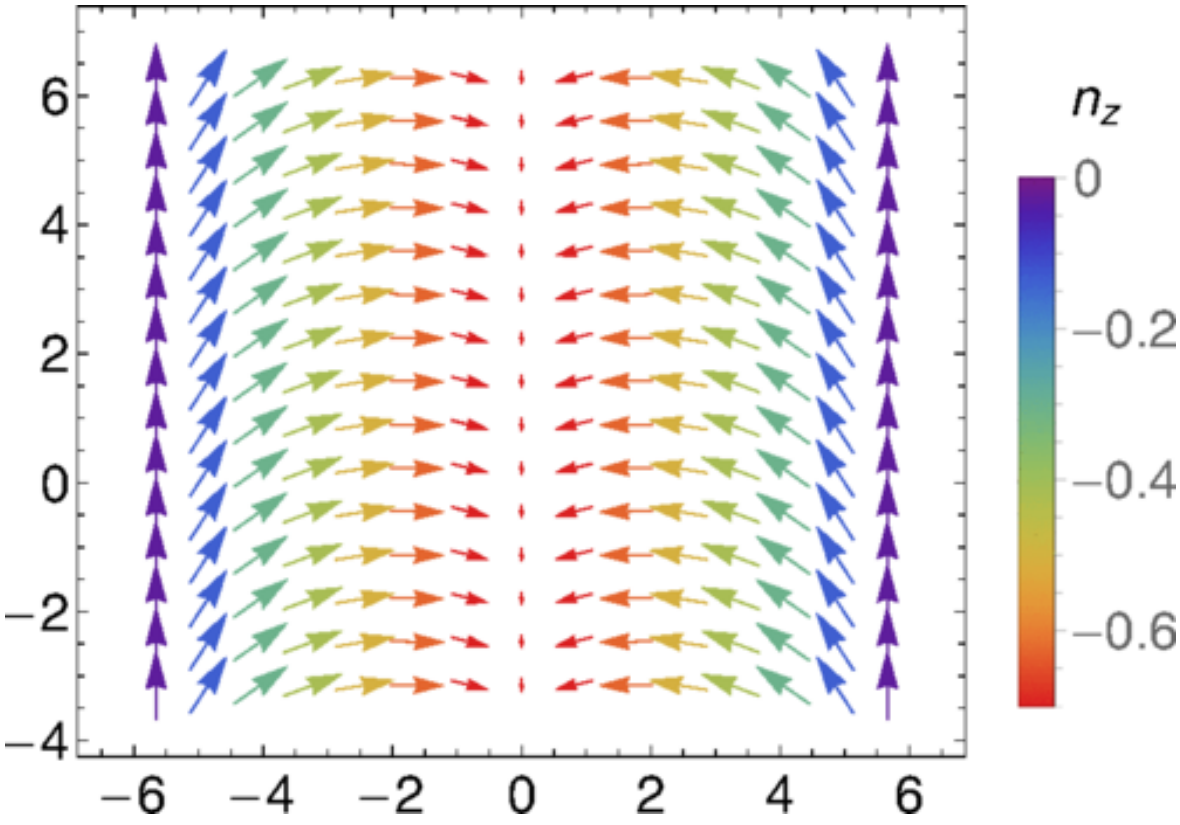
(a)

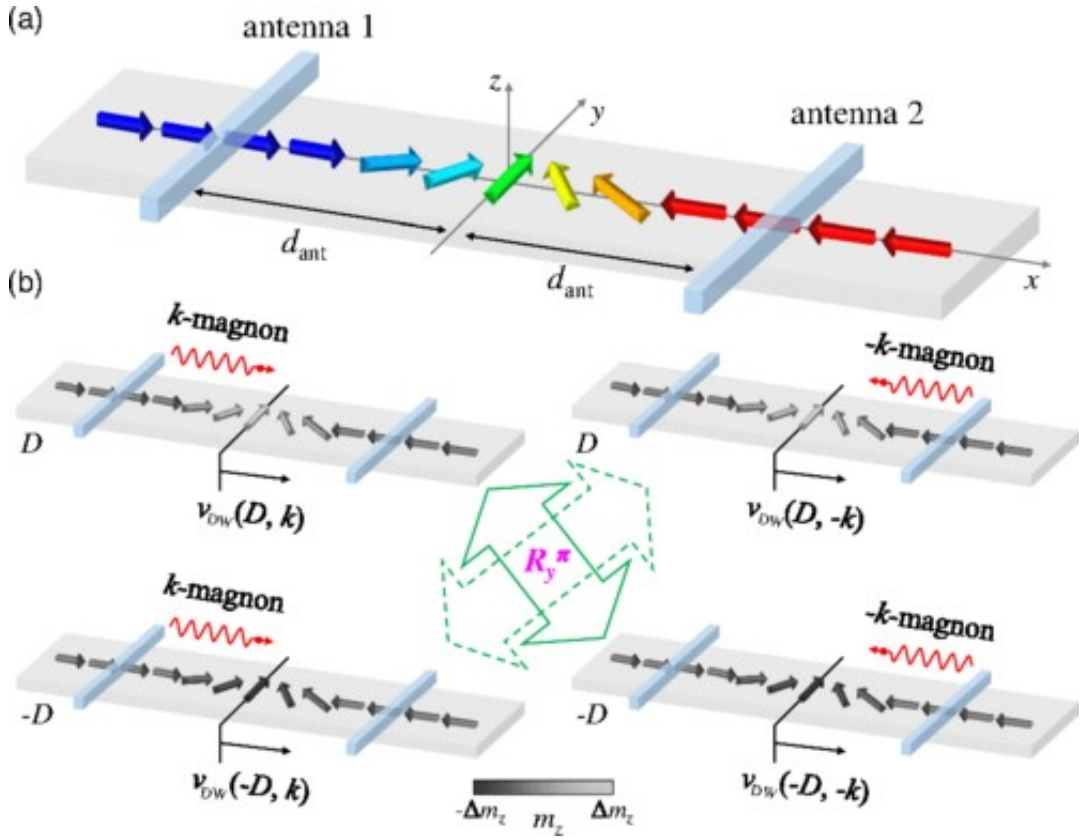

(a)
N=32
C
T
Δ=0.0
Δ=0.3
Δ=0.6
Δ=1.0
(b)
N=32
χ
T
Δ=0.0
Δ=0.3
Δ=0.6
Δ=1.0
O
TM

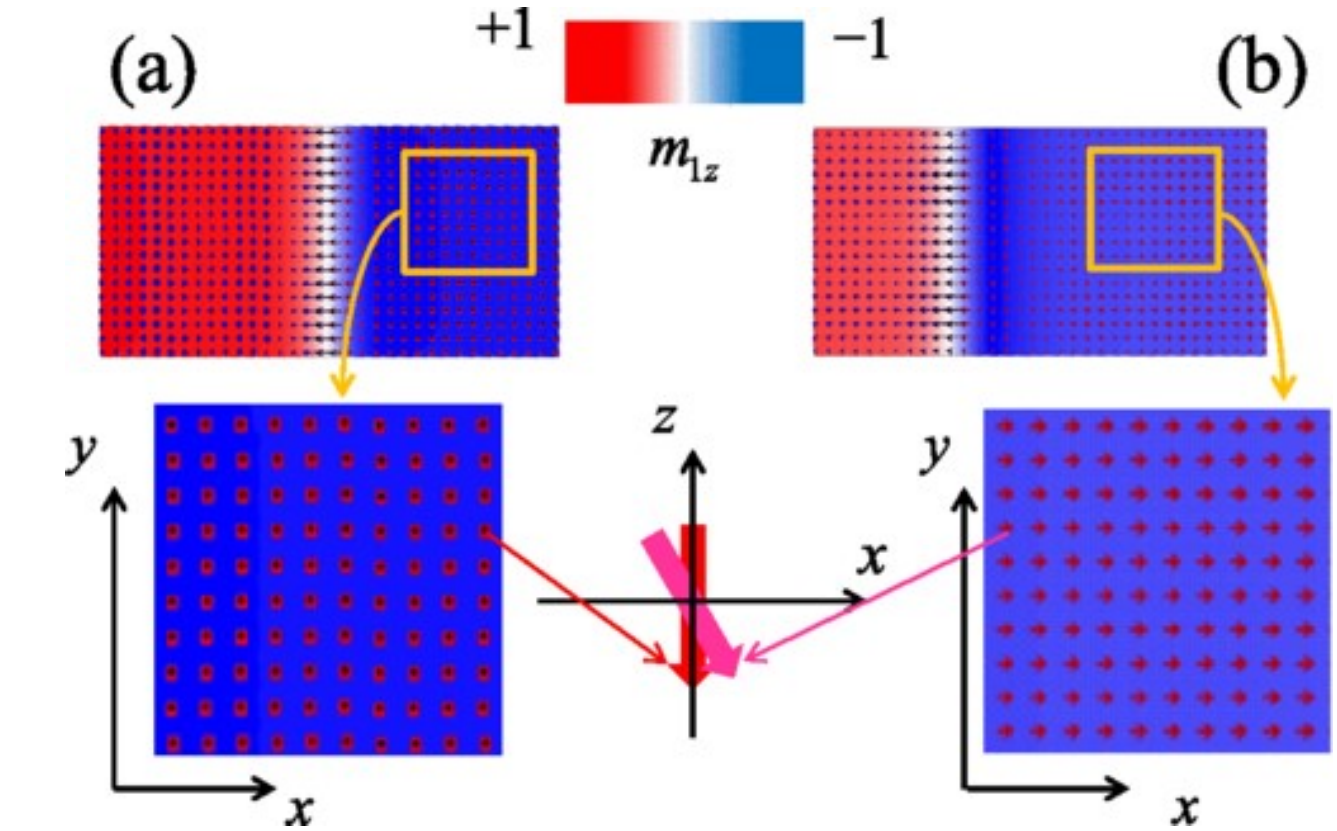
(b)

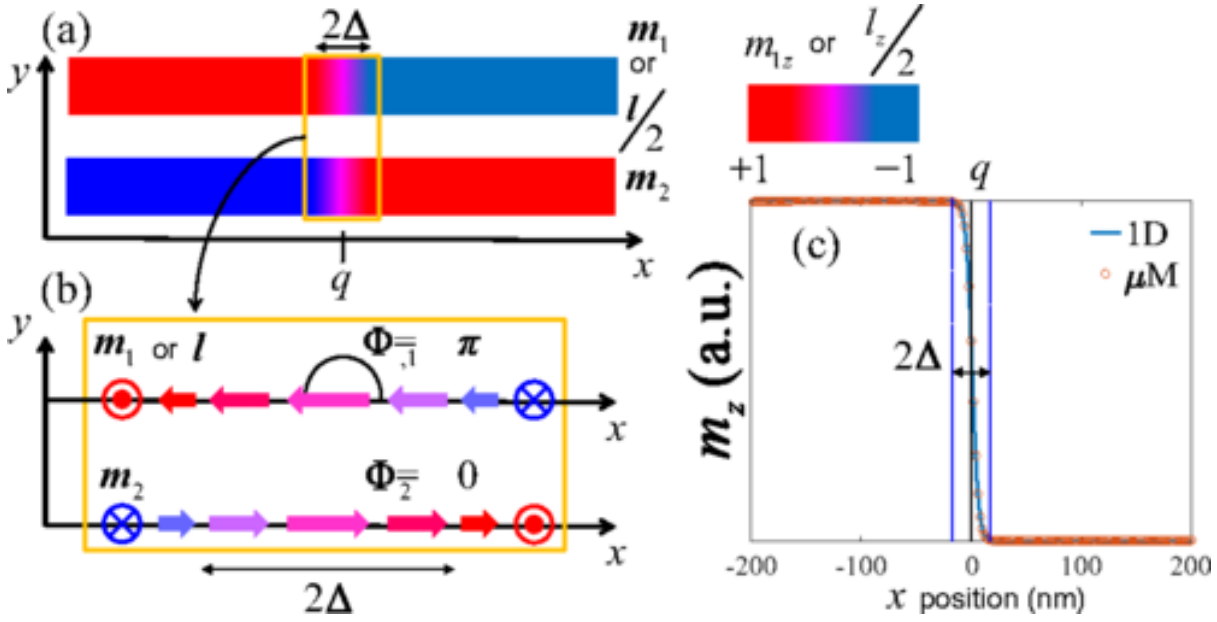

-L
y
x
∇T
z
L
S
Δ
m
φ
θ


(a)
y
x
DMI-magnons torque
(b)
m
x (nm)
m_x
m_y
m_z
$K_\perp^2$
(c)
Frequency (GHz)
k (nm^{-1})
w_{DW}
w_-
w_+
$-k_m$
k_m
(a)
Δ (nm)
κ=$K_\perp$/K
Δ_c
Δ_∞
Δ_0
$\phi'_\infty \sim \sin 2\phi$
$\phi'_\infty = 0$
(b)
$K_\perp$ (MJ/m^3)
D (mJ/m^2)
$\mathbf{j}^s_{in}$
$\mathbf{j}^s_{out}$
$x-\frac{\Delta x}{2}$
$x+\frac{\Delta x}{2}$
$\mathbf{j}^s_{pump}(x-\Delta x)$
$\mathbf{j}^s_{pump}(x)$
$\mathbf{j}^s_{pump}(x+\Delta x)$

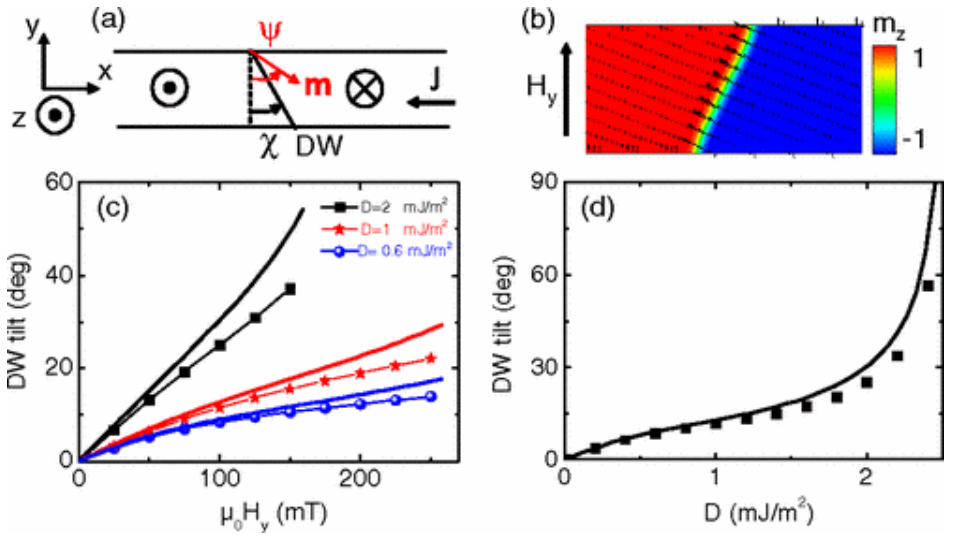

n_z
0
−0.2
−0.4
−0.6
6
4
2
0
−2
−4
−6
−4
−2
0
2
4
6

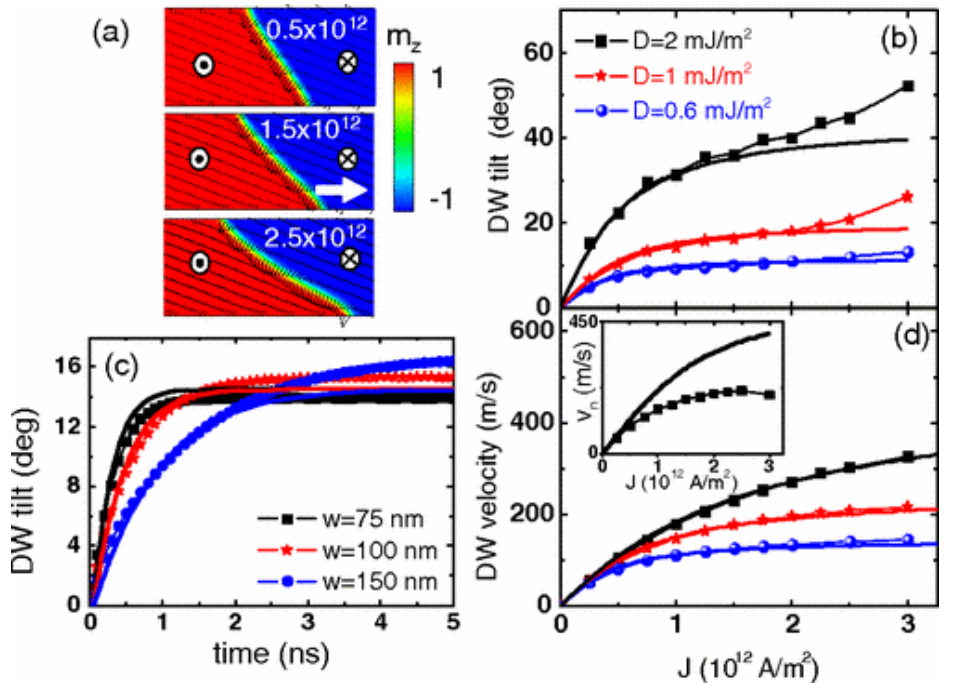

(a)
antenna 1
antenna 2
z
y
x
d_{ant}
d_{ant}
(b)
k-magnon
-k-magnon
D
D
$v_{DW}(D, k)$
$v_{DW}(D, -k)$
R_y^{π}
k-magnon
-k-magnon
-D
-D
$v_{DW}(-D, k)$
$v_{DW}(-D, -k)$
$-\Delta m_z$
m_z
Δm_z

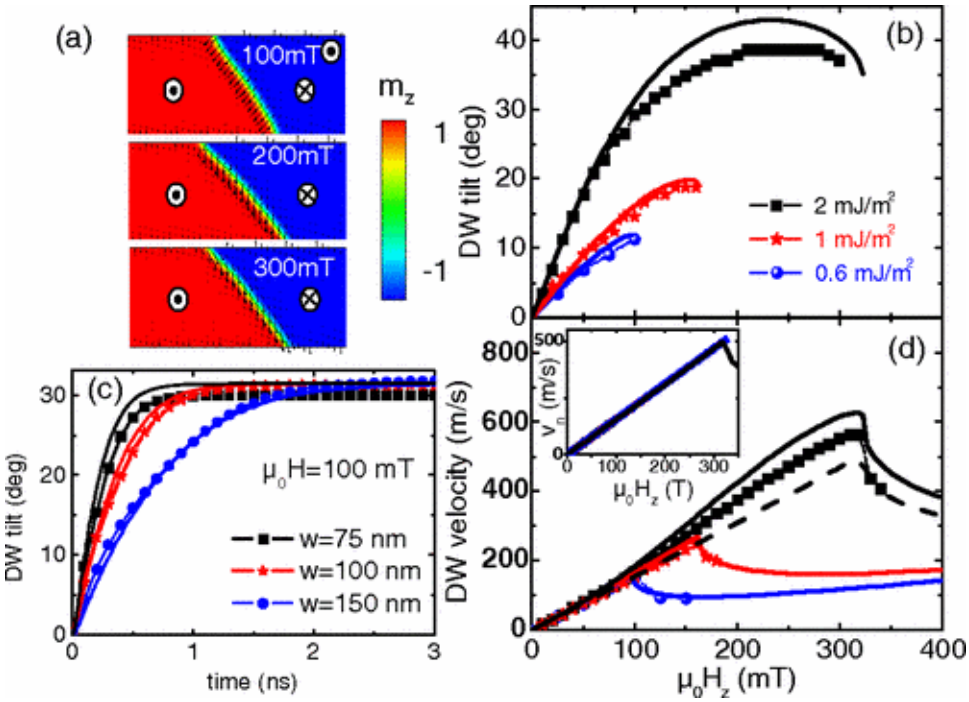

(a)
+1
−1
(b)
m_{1z}
y
x
z
y
x
x

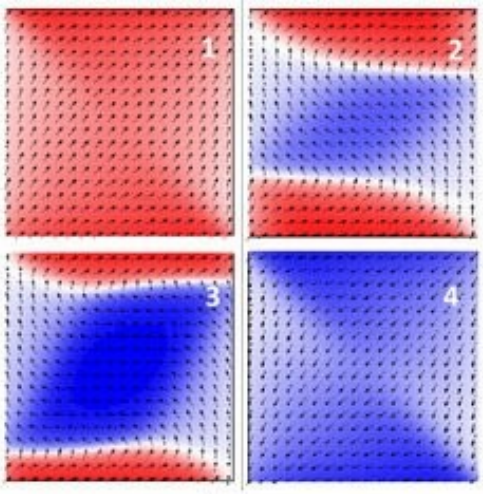

(a)
2Δ
m_1 or $l/2$
m_2
y
x
q
(b)
m_1 or l
$\Phi = \pi$
m_2
$\Phi = 0$
2Δ
m_{1z} or $l_z/2$
+1
−1
q
(c)
1D
μM
2Δ
m_z (a.u.)
-200
-100
0
100
200
x position (nm)

(a)
(b)
(c)
(d)
(e)

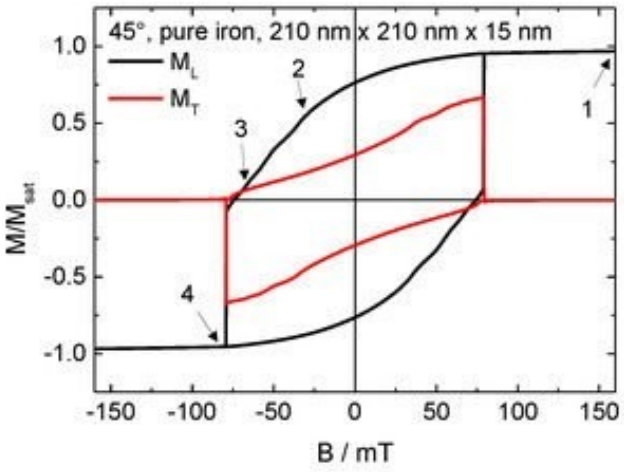

(a)
y
x
z
ψ
m
J
χ DW
(b)
H_y
m_z
1
-1
(c)
D=2 mJ/m²
D=1 mJ/m²
D= 0.6 mJ/m²
DW tilt (deg)
μ_0H_y (mT)
(d)
DW tilt (deg)
D (mJ/m²)


(a)
0.5x10¹²
1.5x10¹²
2.5x10¹²
m_z
1
-1
(b)
D=2 mJ/m²
D=1 mJ/m²
D=0.6 mJ/m²
DW tilt (deg)
(c)
DW tilt (deg)
w=75 nm
w=100 nm
w=150 nm
time (ns)
(d)
DW velocity (m/s)
v_n (m/s)
J (10¹² A/m²)

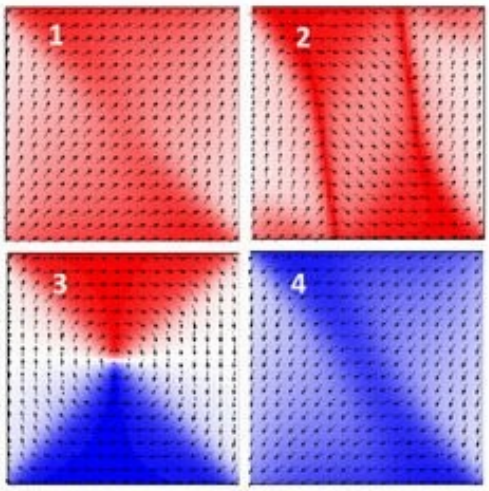

(a)
100mT
200mT
300mT
m_z
1
-1
(b)
2 mJ/m²
1 mJ/m²
0.6 mJ/m²
DW tilt (deg)
(c)
μ_0H=100 mT
w=75 nm
w=100 nm
w=150 nm
DW tilt (deg)
time (ns)
(d)
DW velocity (m/s)
v_n (m/s)
μ_0H_z (T)
μ_0H_z (mT)


1
2
3
4

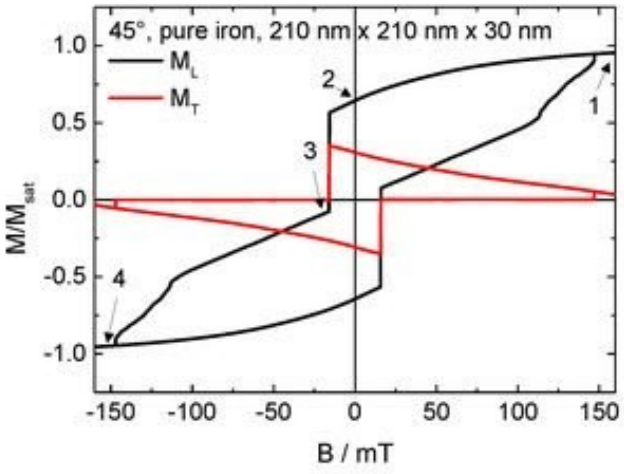
(a)


45°, pure iron, 210 nm x 210 nm x 15 nm
M_L
M_T
M/M_sat
B / mT
1.0
0.5
0.0
-0.5
-1.0
-150
-100
-50
0
50
100
150
1
2
3
4

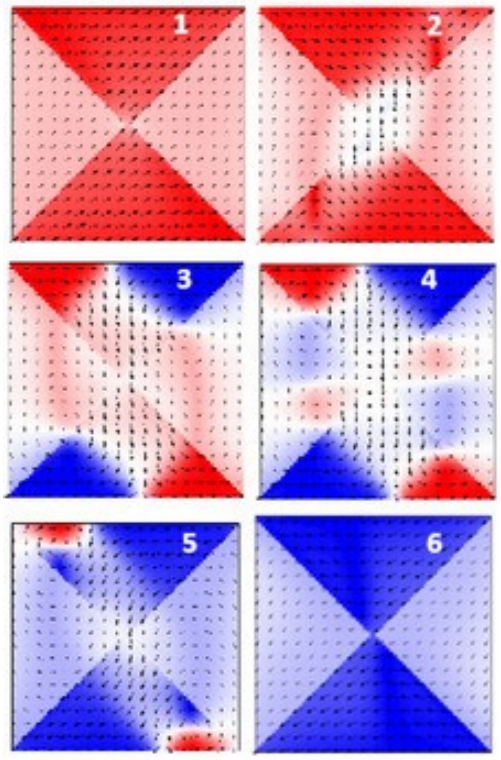
(b)


1
2
3
4

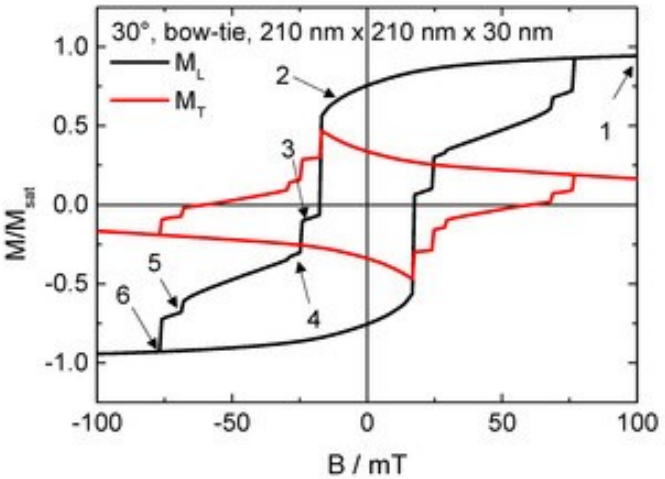
(c)


45°, pure iron, 210 nm x 210 nm x 30 nm
M_L
M_T
M/M_sat
B / mT
1.0
0.5
0.0
-0.5
-1.0
-150
-100
-50
0
50
100
150
1
2
3
4

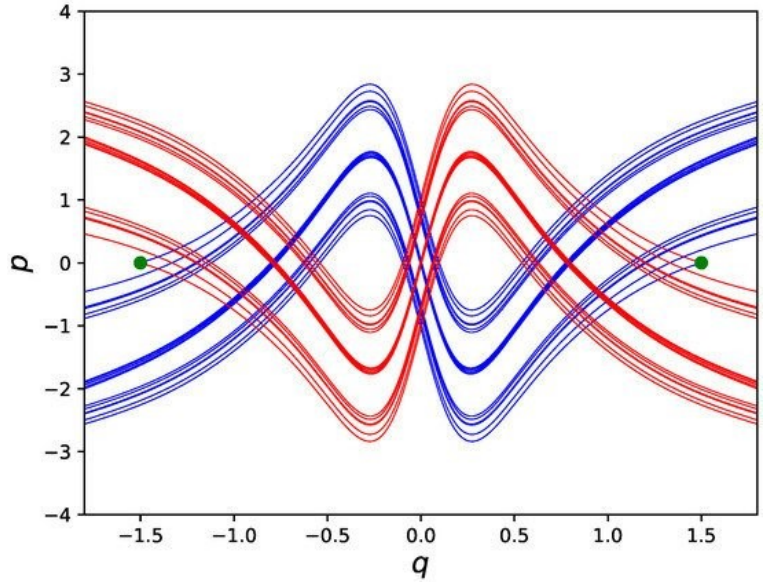
(d)

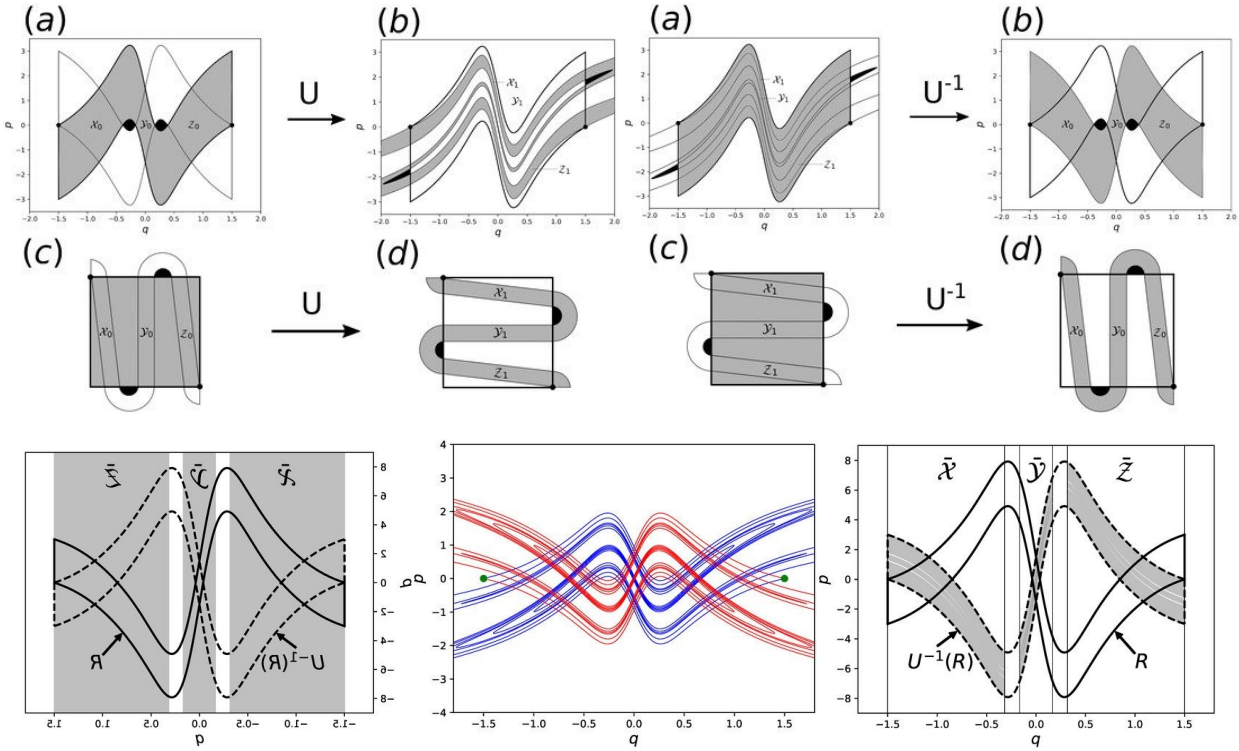

1
2
3
4
5
6

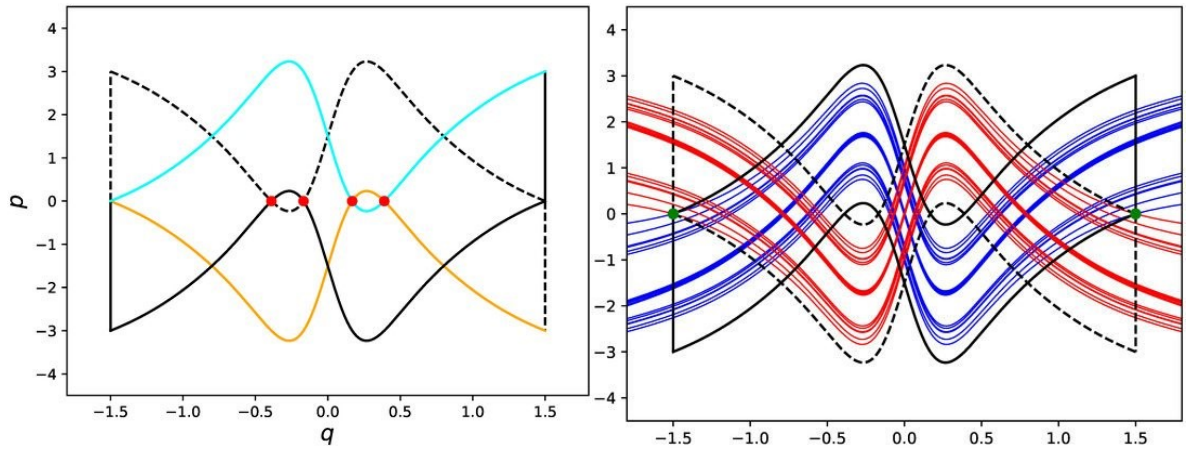
(a)

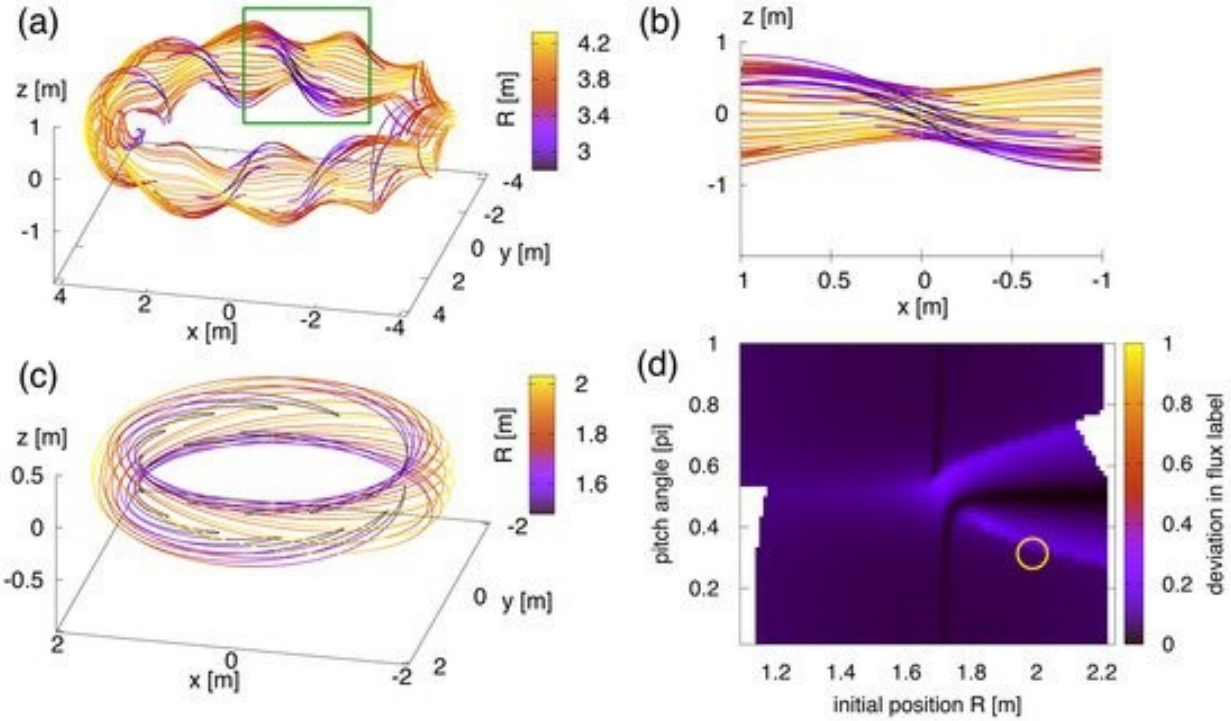

30°, bow-tie, 210 nm x 210 nm x 30 nm
M_L
M_T
M/M_sat
B / mT
1.0
0.5
0.0
-0.5
-1.0
-100
-50
0
50
100
1
2
3
4
5
6

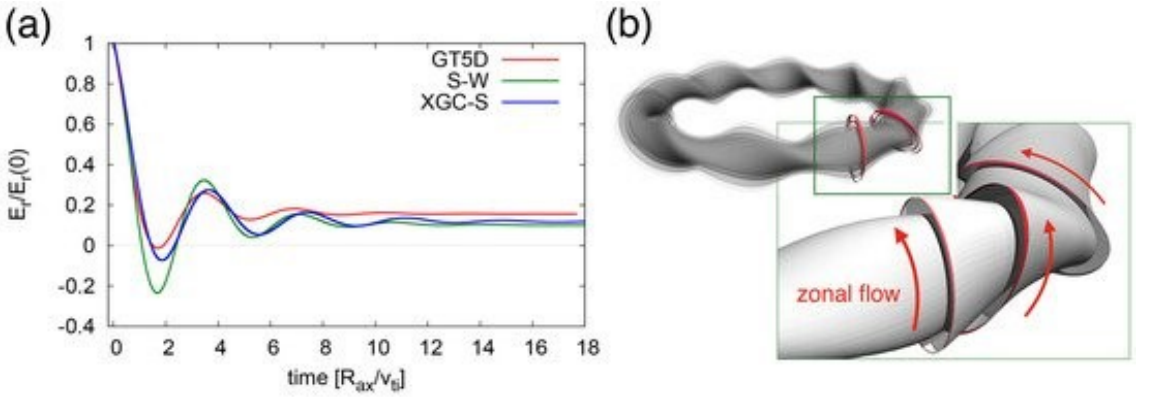
(b)

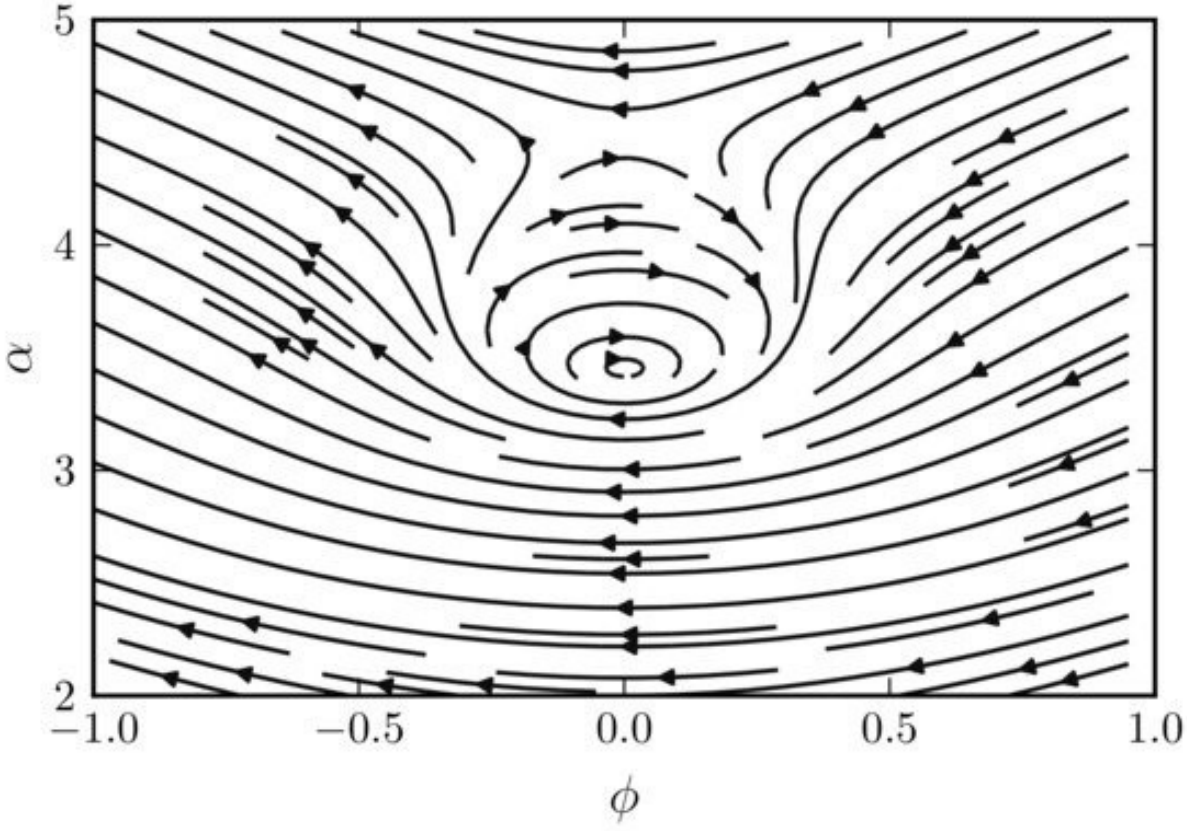

p
q

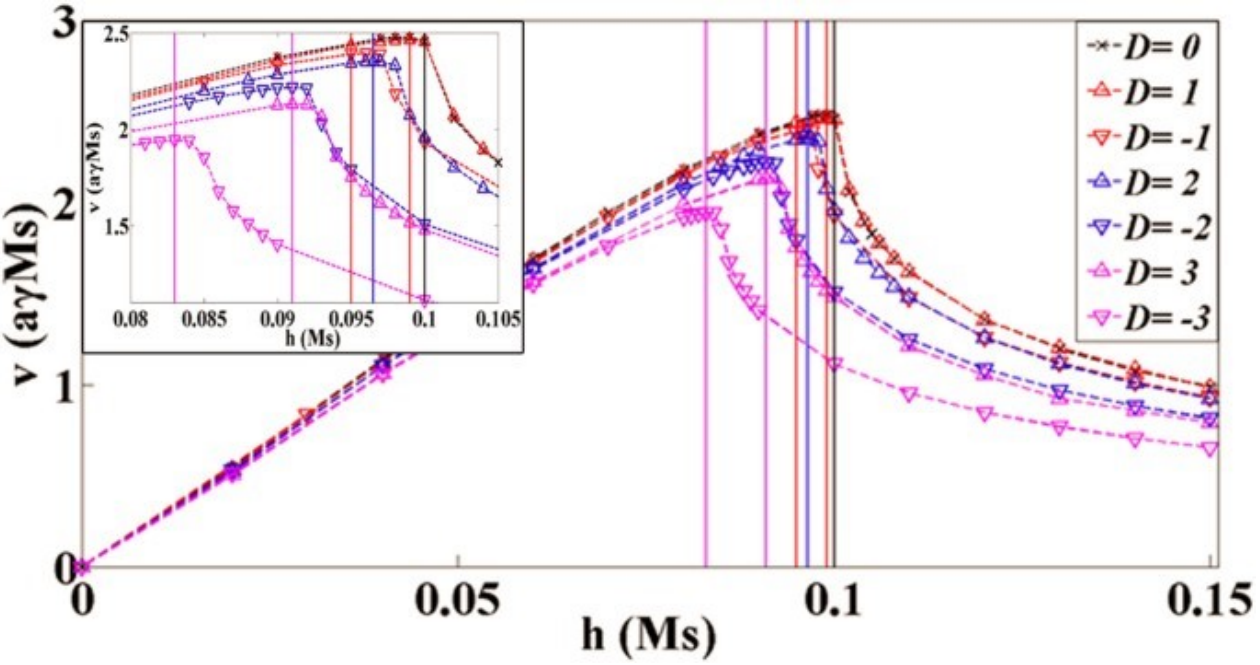

(a)
(b)
U
(a)
(b)
U-1
(c)
(d)
U
(c)
(d)
U-1
R
U−1(R)
U−1(R)
R
p
q

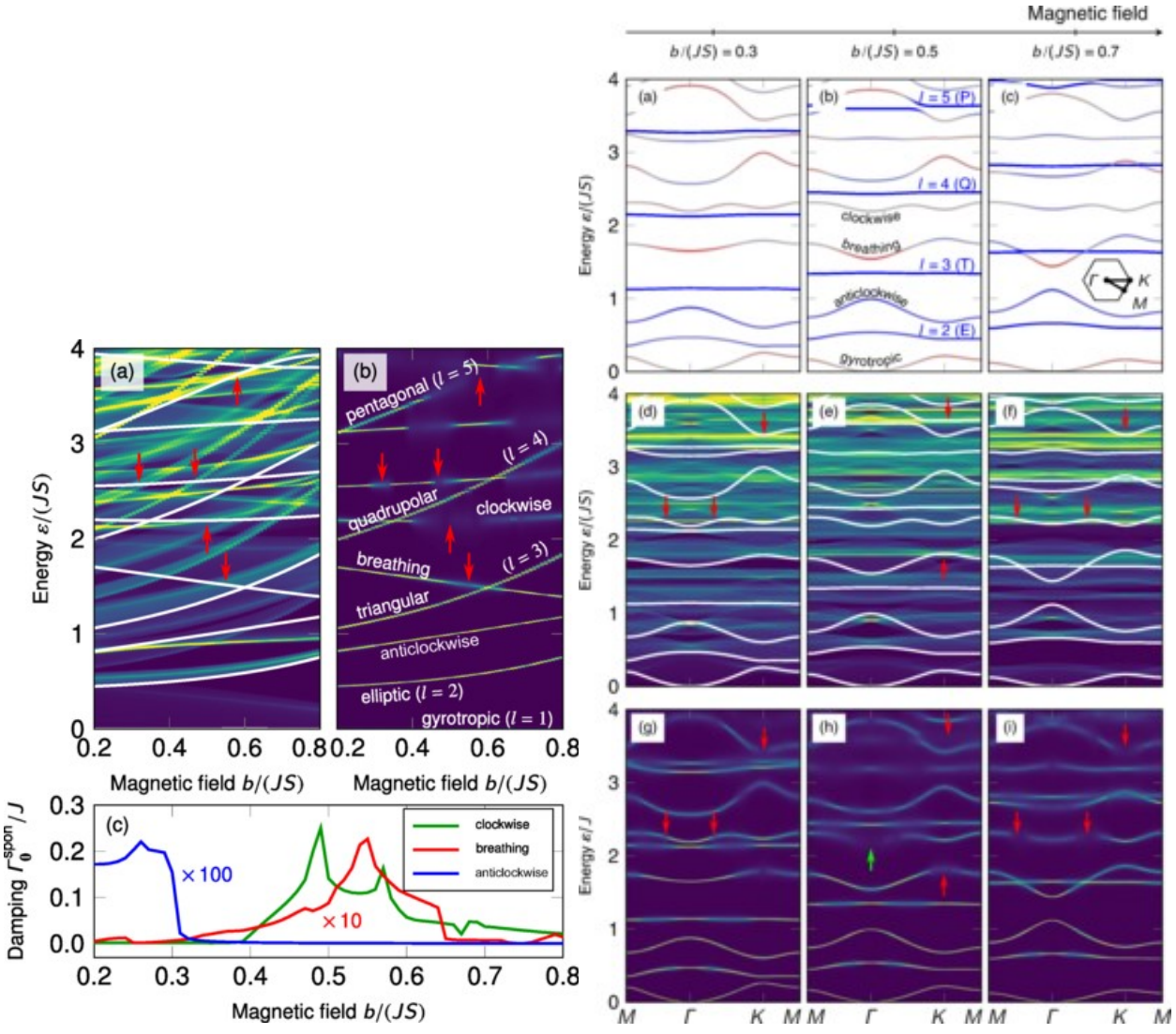

p
q

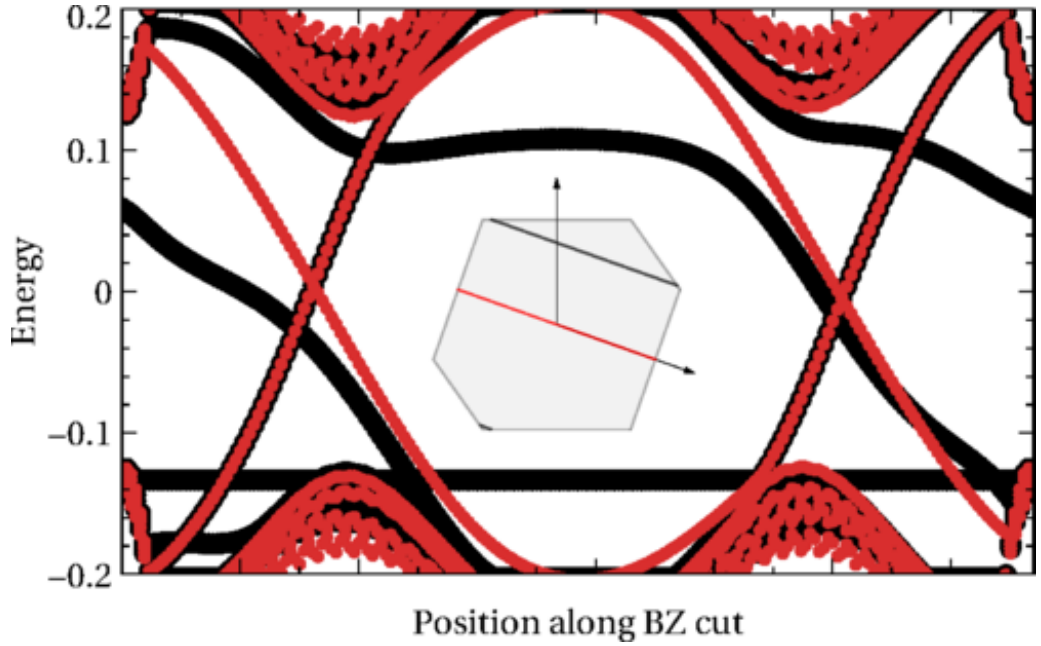

(a)
z [m]
R [m]
x [m]
y [m]
(b)
z [m]
x [m]
(c)
z [m]
R [m]
x [m]
y [m]
(d)
pitch angle [pi]
initial position R [m]
deviation in flux label

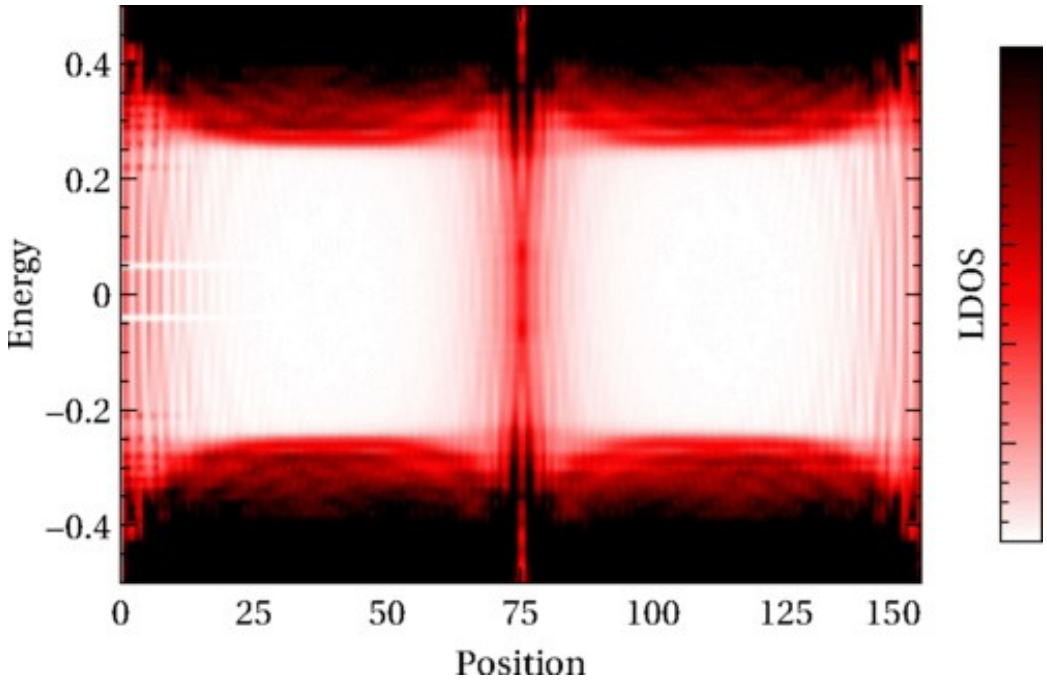

(a)
GT5D
S-W
XGC-S
$E_r/E_r(0)$
time [R_{ax}/v_{ti}]
(b)
zonal flow

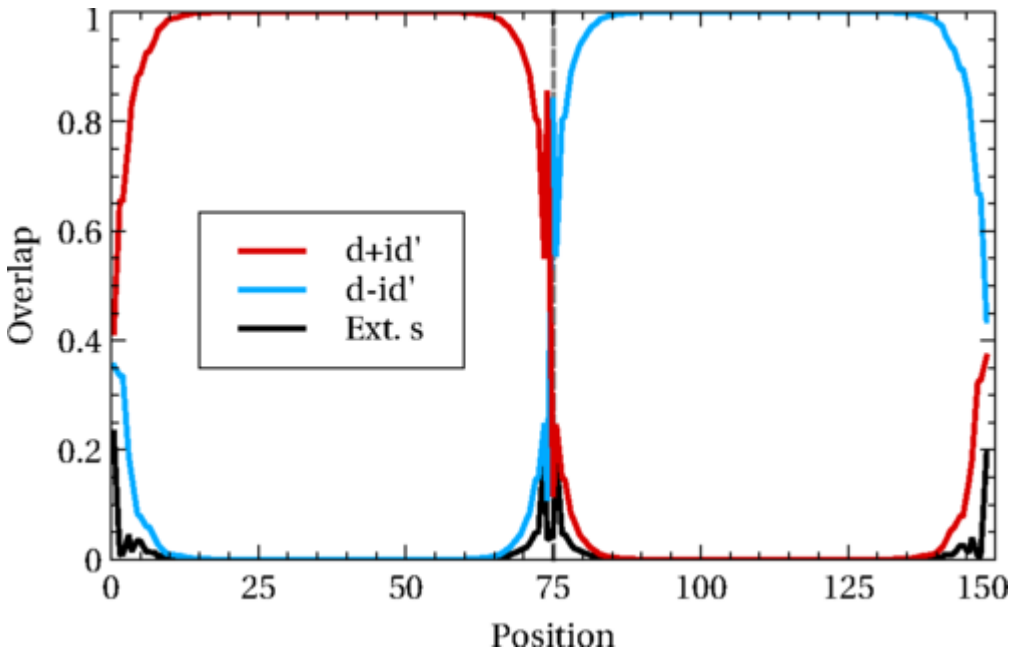

α
ϕ

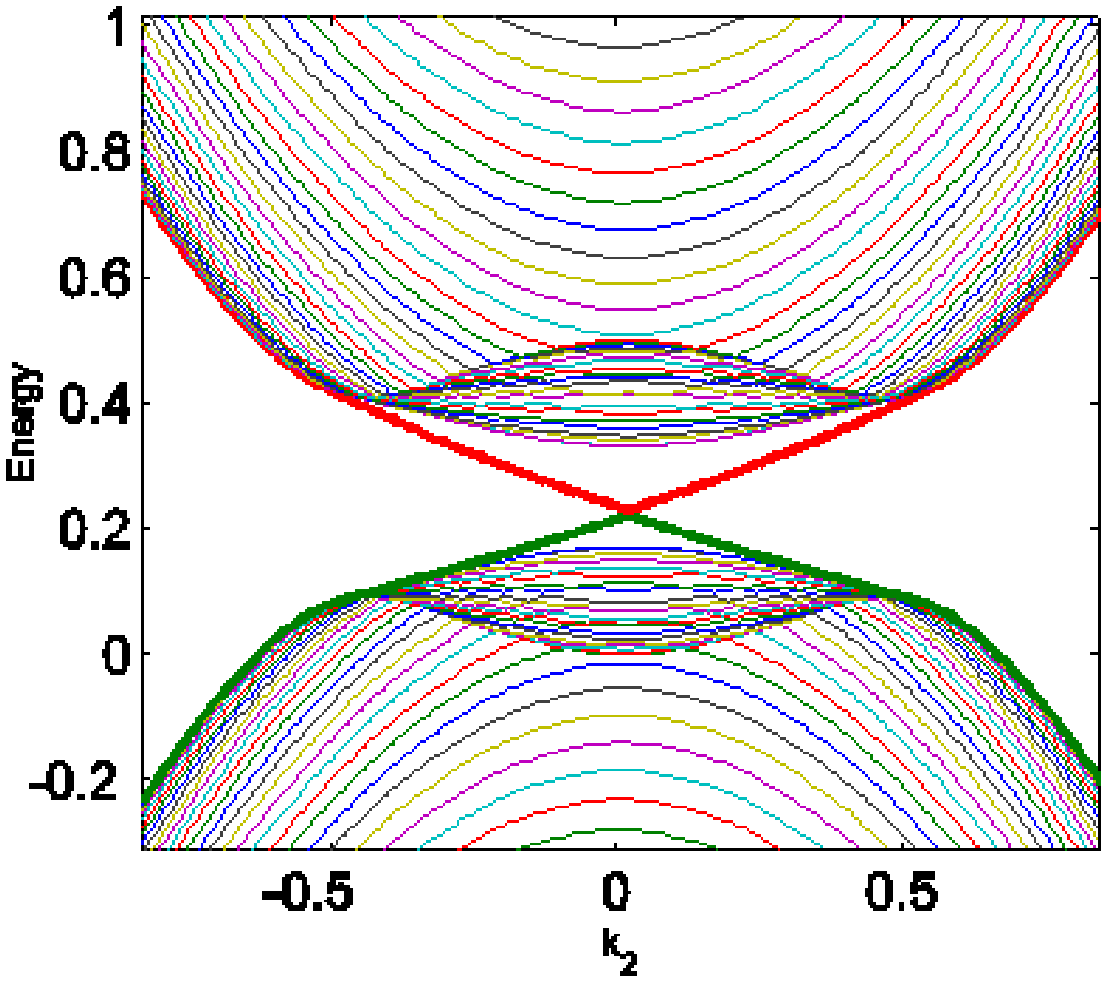

D= 0
D= 1
D= -1
D= 2
D= -2
D= 3
D= -3
ν (aγMs)
h (Ms)
0
0.05
0.1
0.15
1
2
3
0.08
0.085
0.09
0.095
0.1
0.105
1.5
2
2.5

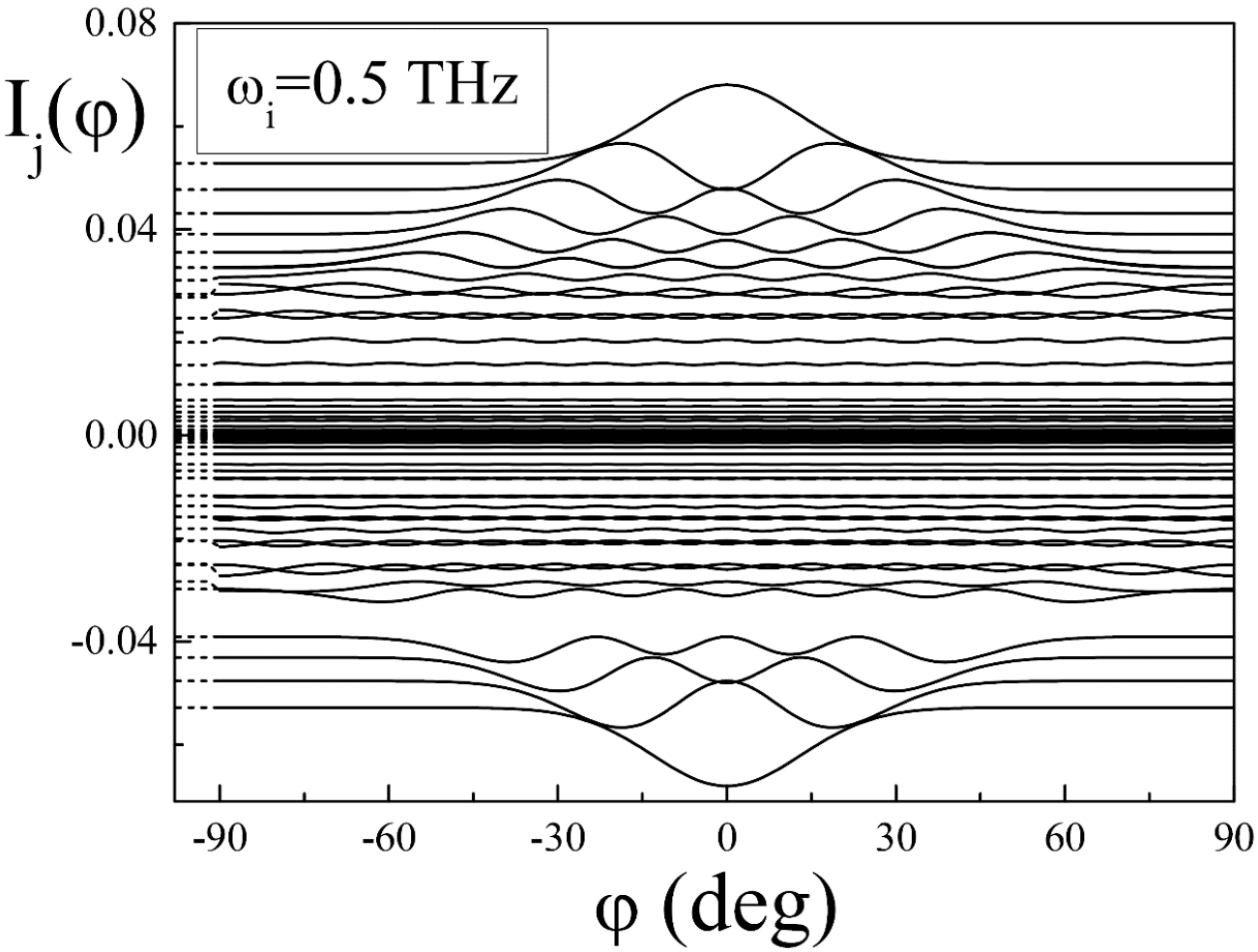

Magnetic field
b/(JS) = 0.3
b/(JS) = 0.5
b/(JS) = 0.7
(a)
(b)
(c)
(d)
(e)
(f)
(g)
(h)
(i)
l = 5 (P)
l = 4 (Q)
clockwise
breathing
l = 3 (T)
anticlockwise
l = 2 (E)
gyrotropic
Γ
K
M
Energy ε/(JS)
Energy ε/J
pentagonal (l = 5)
(l = 4)
quadrupolar
clockwise
breathing
(l = 3)
triangular
anticlockwise
elliptic (l = 2)
gyrotropic (l = 1)
Magnetic field b/(JS)
Damping Γ0spon/J
×100
×10
clockwise
breathing
anticlockwise

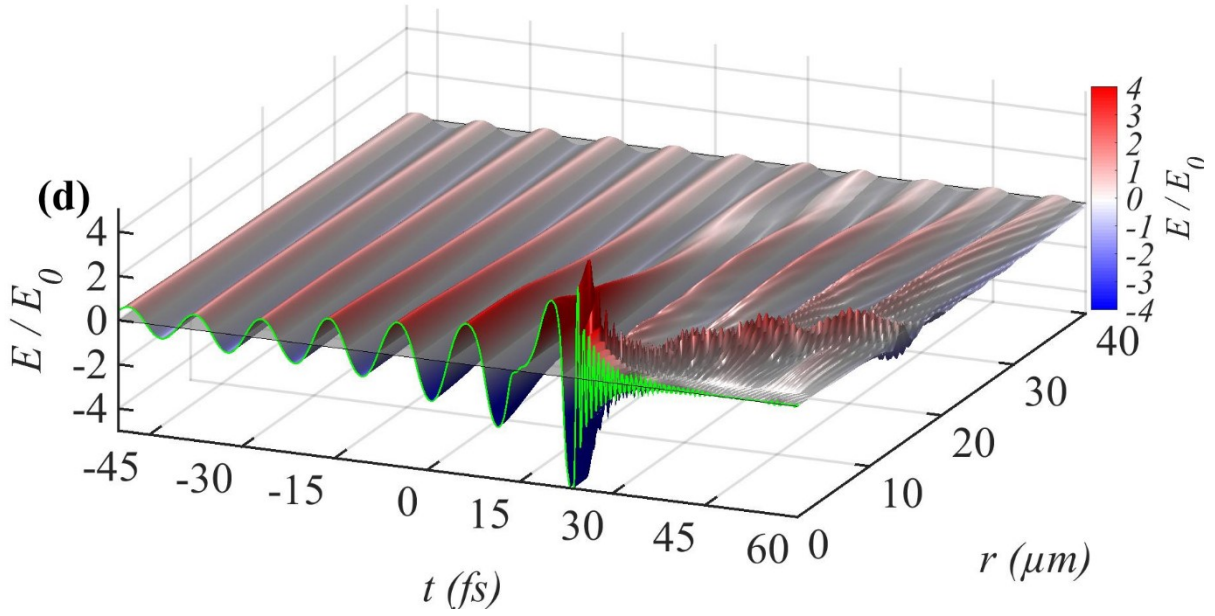

0.2
0.1
0
−0.1
−0.2
Energy
Position along BZ cut

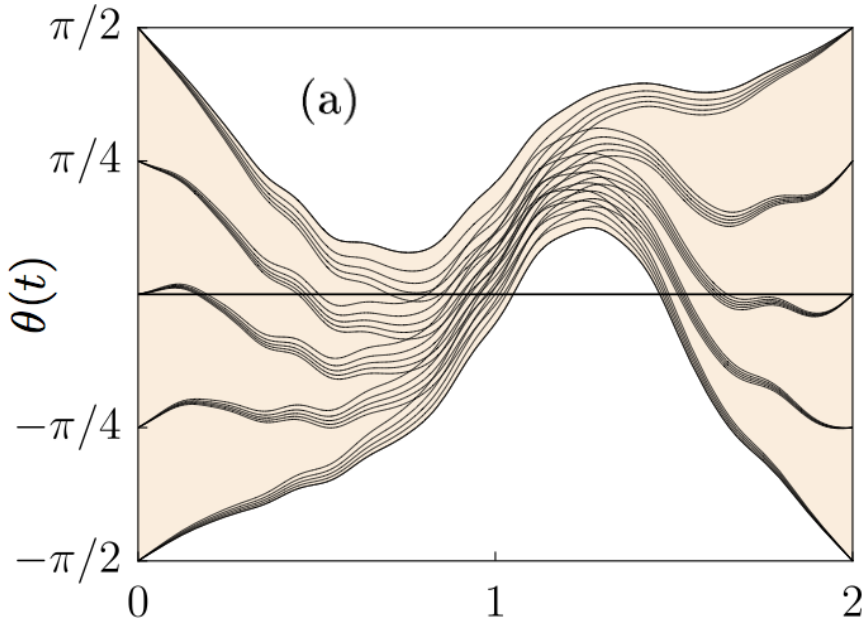

0.4
0.2
0
−0.2
−0.4
Energy
0
25
50
75
100
125
150
Position
LDOS

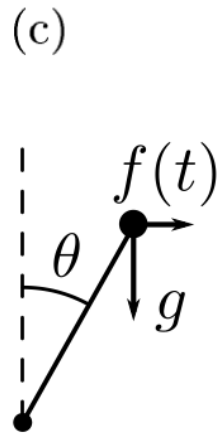

1
0.8
0.6
0.4
0.2
0
Overlap
d+id'
d-id'
Ext. s
0
25
50
75
100
125
150
Position

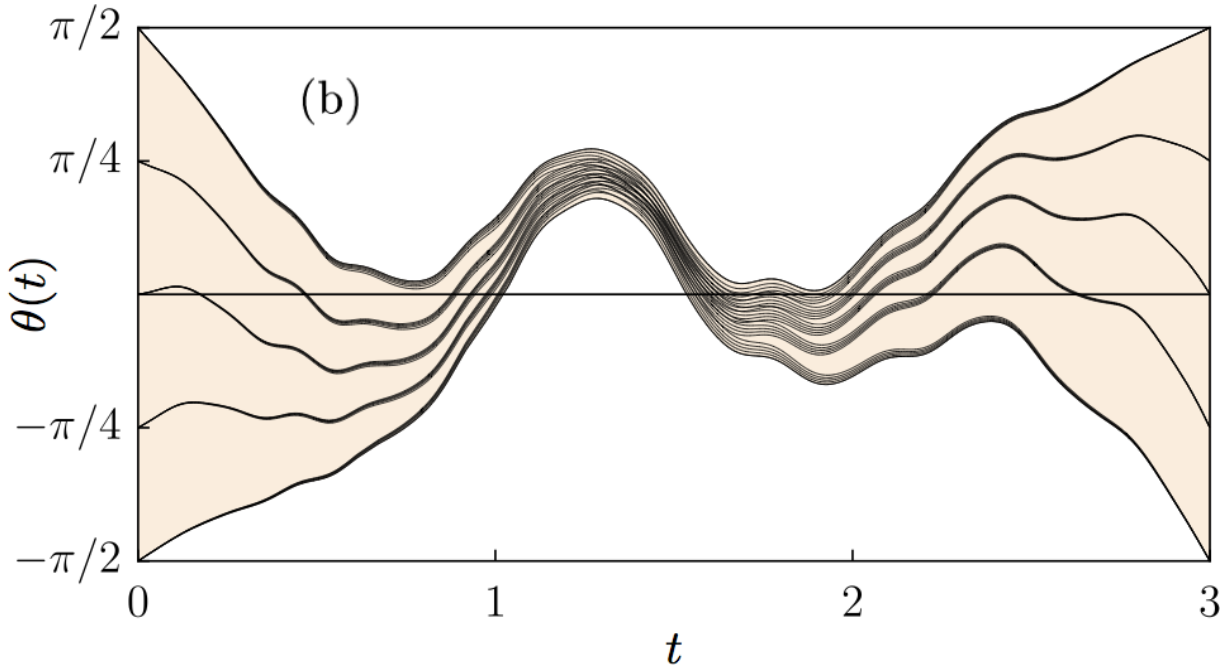

1
0.8
0.6
0.4
0.2
0
-0.2
Energy
-0.5
0
0.5
k2


0.08
0.04
0.00
-0.04
Ij(φ)
ωi=0.5 THz
-90
-60
-30
0
30
60
90
φ (deg)

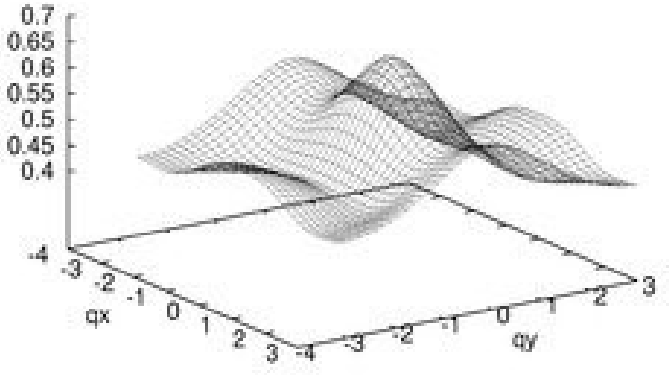

(d)
E / E0
4
2
0
-2
-4
-45
-30
-15
0
15
30
45
60
t (fs)
0
10
20
30
40
r (μm)
4
3
2
1
0
-1
-2
-3
-4
E / E0


(a)
π/2
π/4
−π/4
−π/2
θ(t)
0
1
2

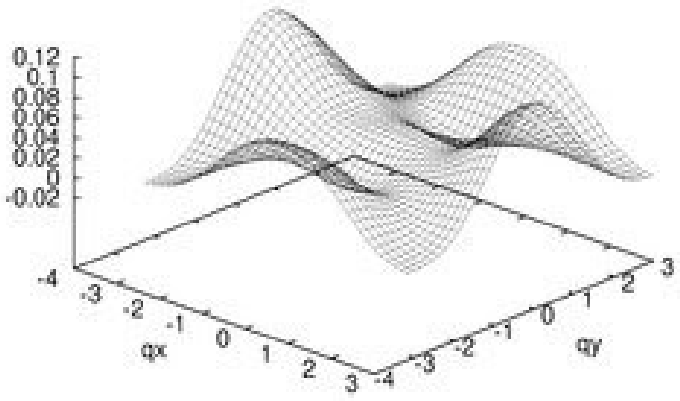

(c)
f(t)
θ
g


(b)
π/2
π/4
−π/4
−π/2
θ(t)
0
1
2
3
t

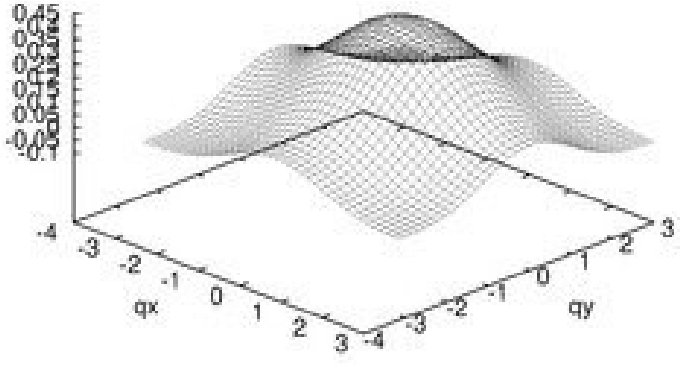
a)

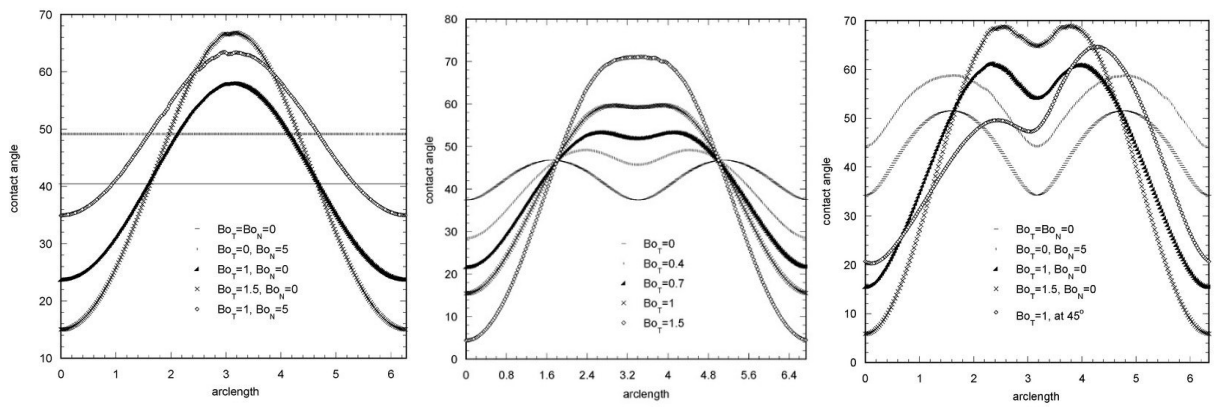

0.7
0.65
0.6
0.55
0.5
0.45
0.4
-4
-3
-2
-1
0
1
2
3
qx
qy

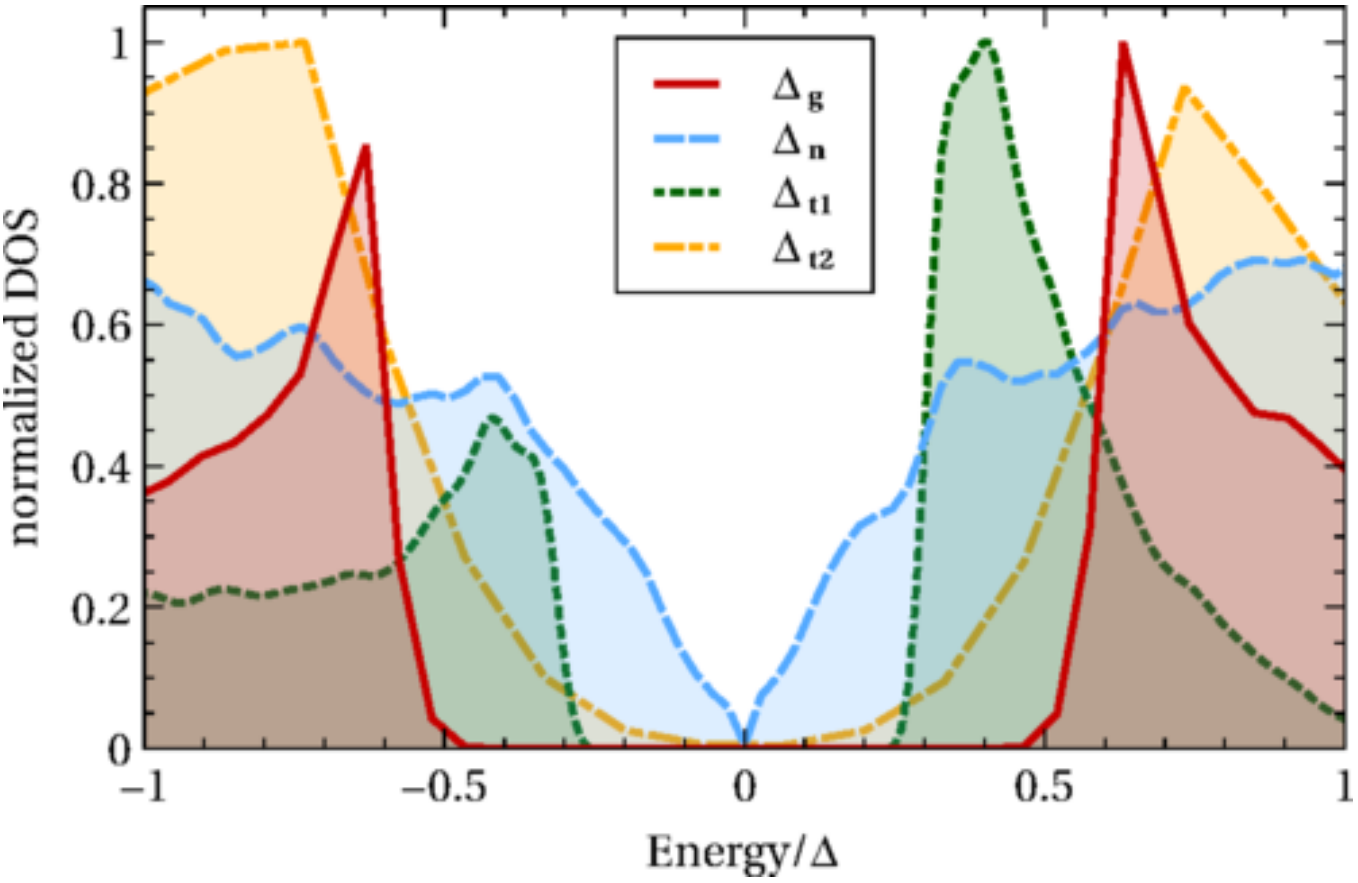
b)

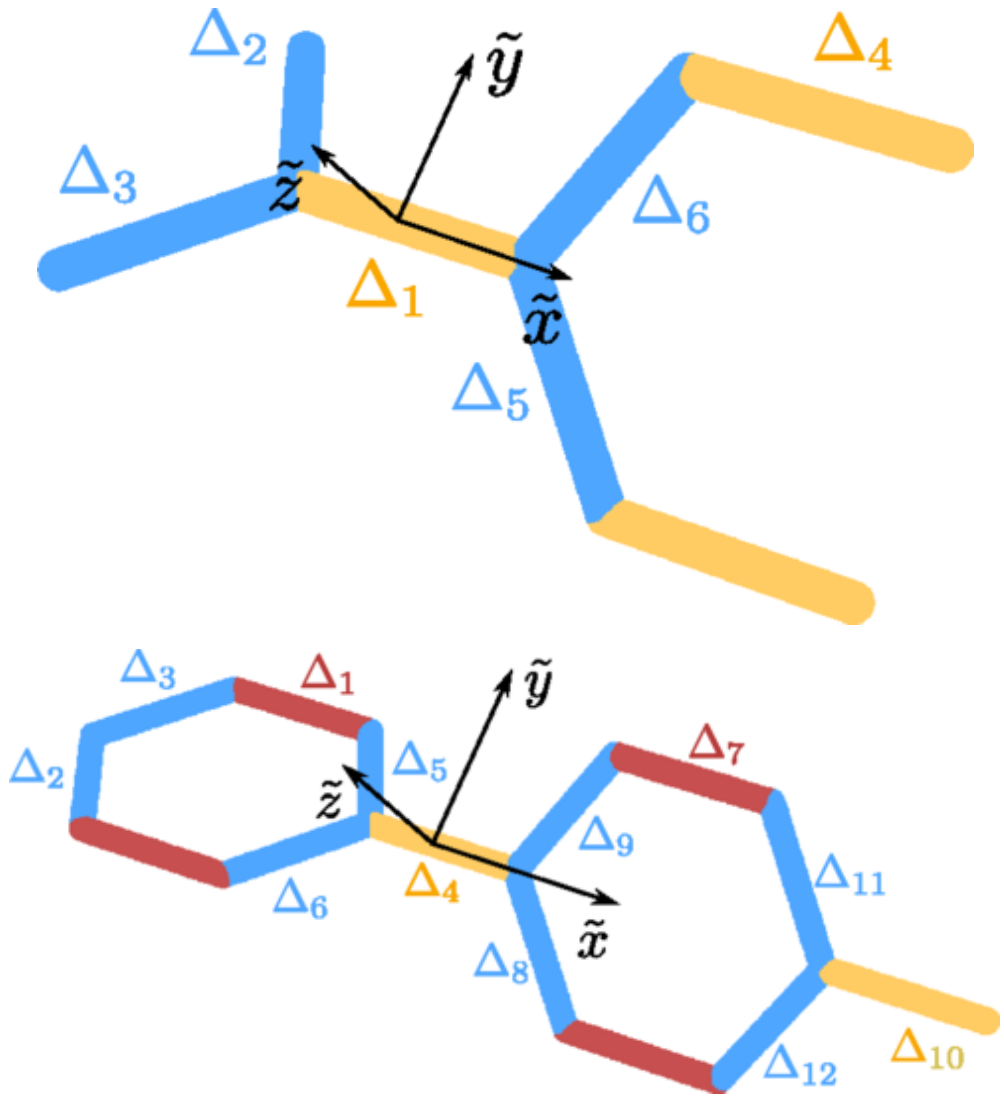

0.12
0.1
0.08
0.06
0.04
0.02
0
-0.02
-4
-3
-2
-1
0
1
2
3
qx
qy

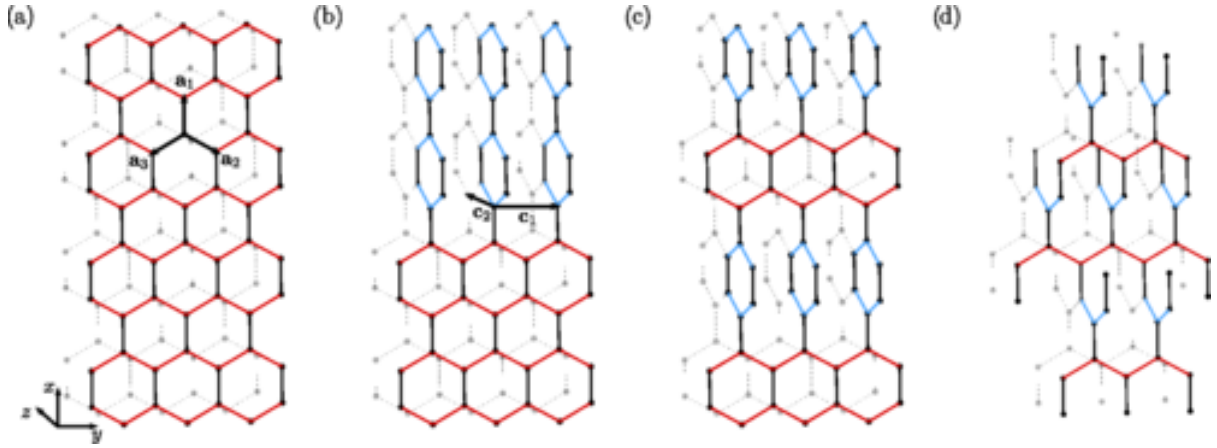
c)

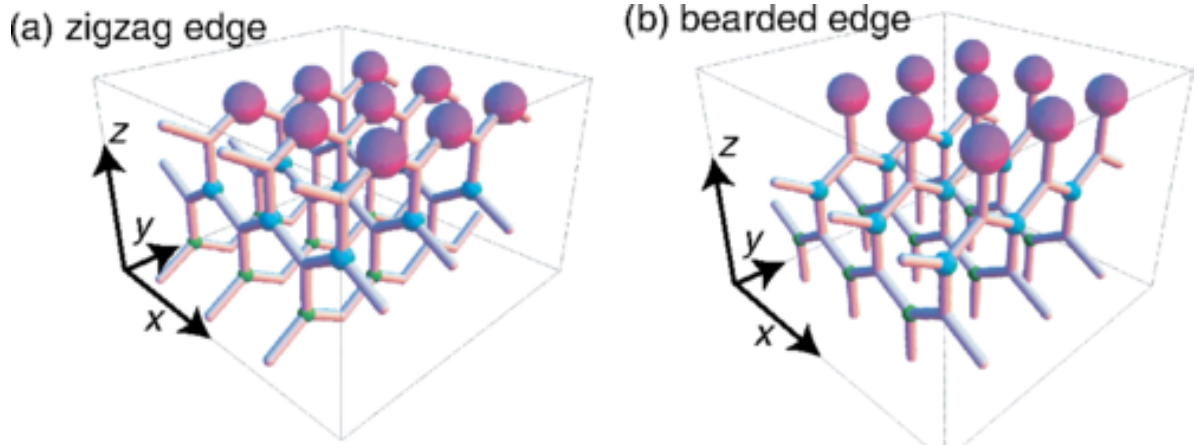

-4
-3
-2
-1
0
1
2
3
qx
qy

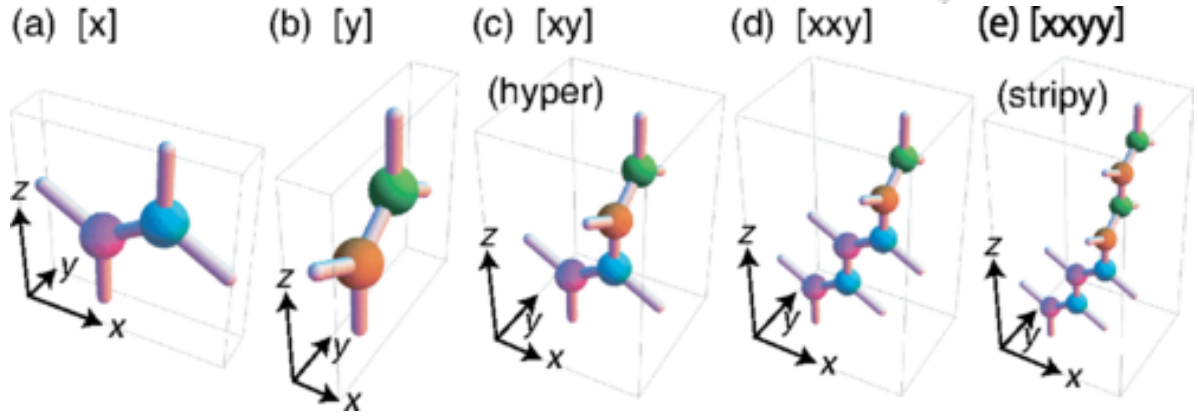

contact angle
arclength
Bo_T=Bo_N=0
Bo_T=0, Bo_N=5
Bo_T=1, Bo_N=0
Bo_T=1.5, Bo_N=0
Bo_T=1, Bo_N=5
Bo_T=0
Bo_T=0.4
Bo_T=0.7
Bo_T=1
Bo_T=1.5
Bo_T=1, at 45°

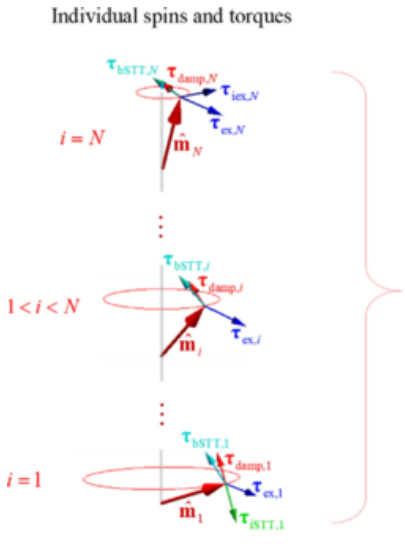

normalized DOS
Energy/Δ
Δg
Δn
Δt1
Δt2
1
0.8
0.6
0.4
0.2
0
−1
−0.5
0
0.5
1

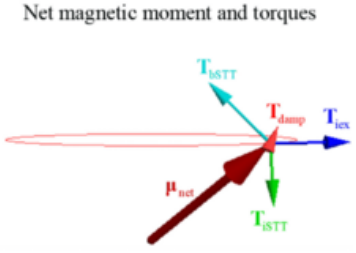

Δ2
Δ3
Δ4
Δ6
Δ1
Δ5
ỹ
z̃
x̃
Δ3
Δ1
Δ2
Δ5
Δ7
Δ9
Δ11
Δ6
Δ4
Δ8
Δ12
Δ10
ỹ
z̃
x̃

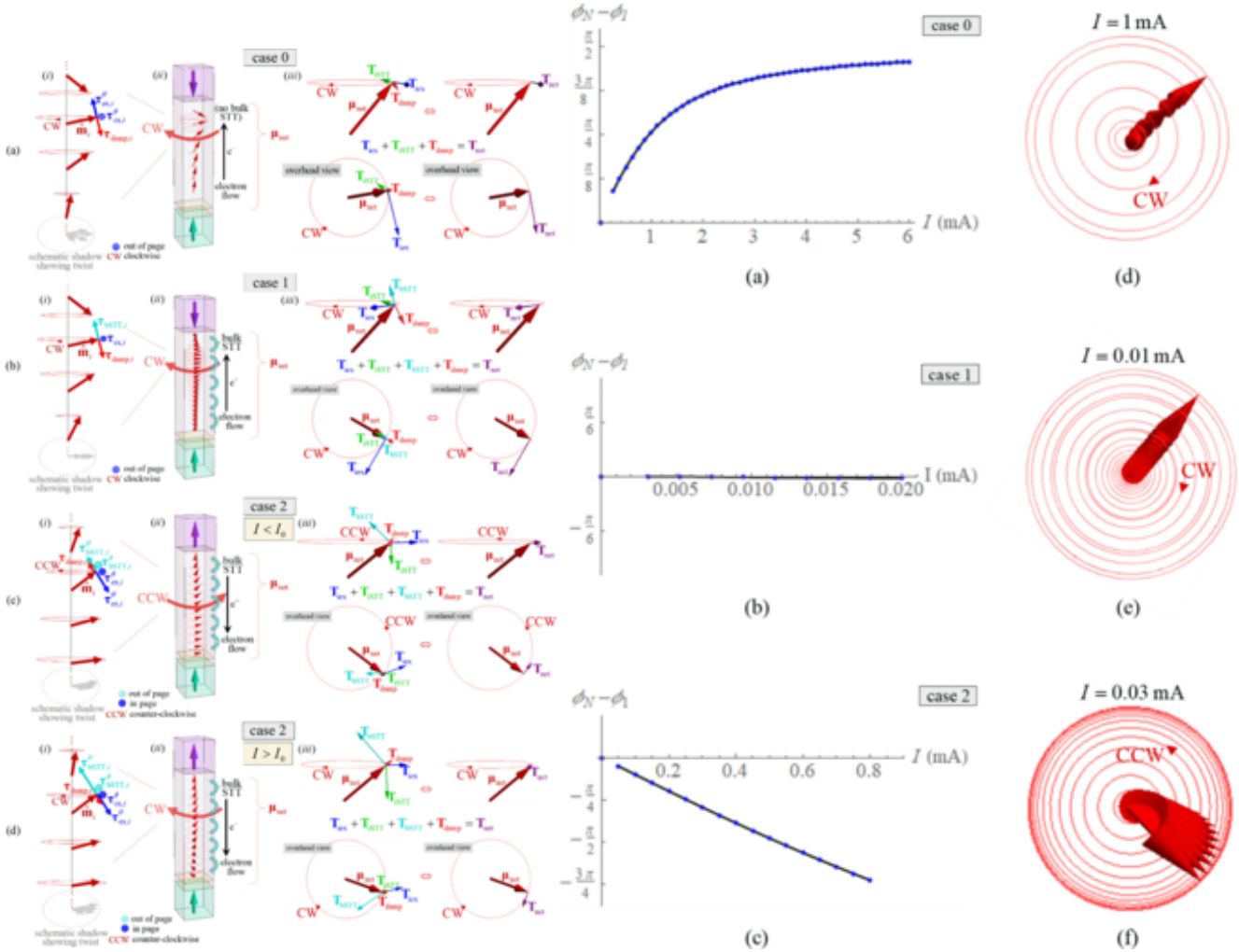

(a)
(b)
(c)
(d)
a1
a2
a3
c1
c2
z
y

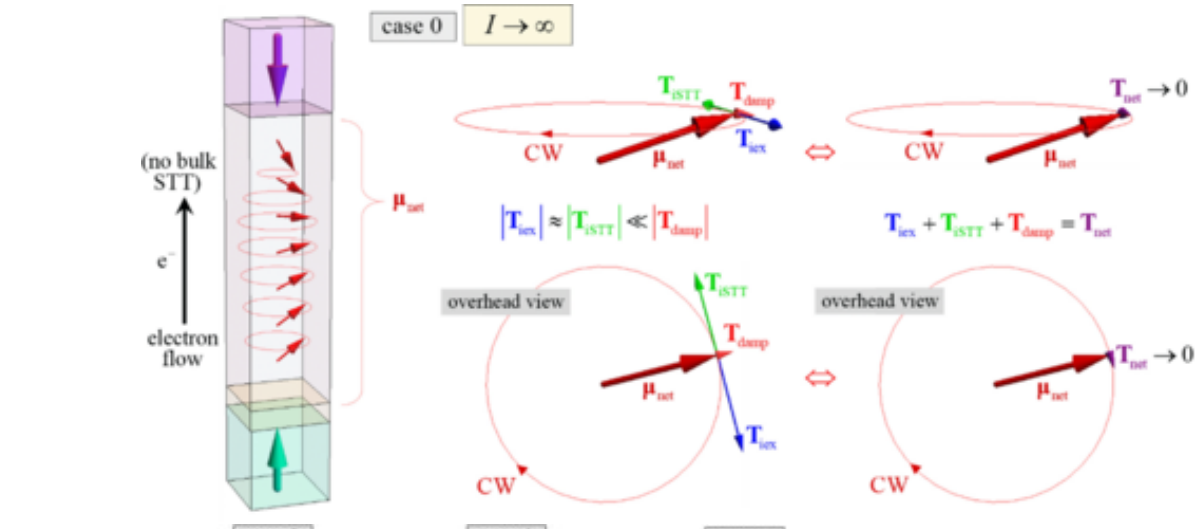

(a) zigzag edge
(b) bearded edge
z
y
x

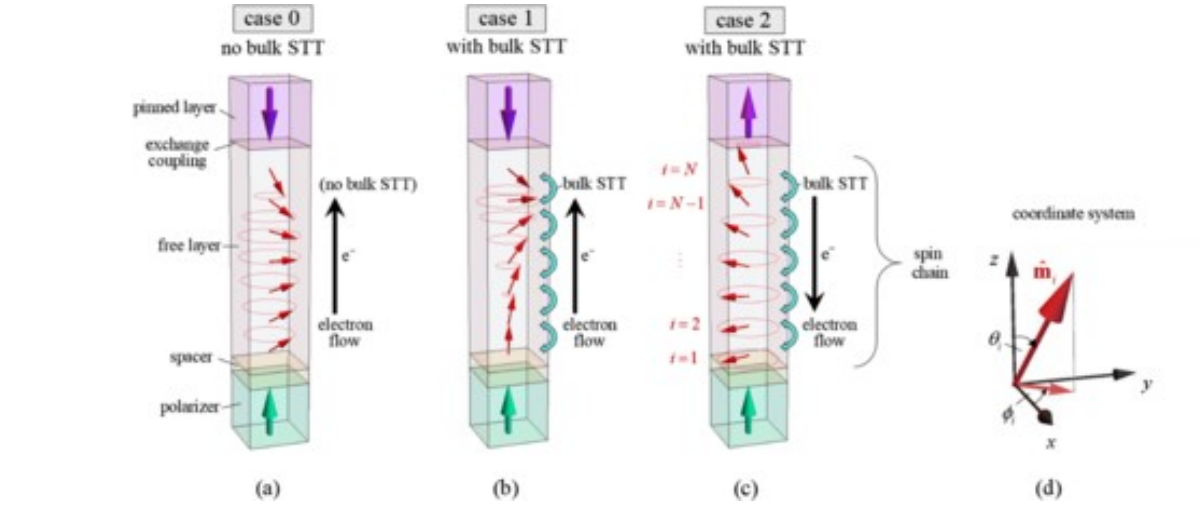

(a) [x]
(b) [y]
(c) [xy]
(hyper)
(d) [xxy]
(e) [xxyy]
(stripy)
z
y
x

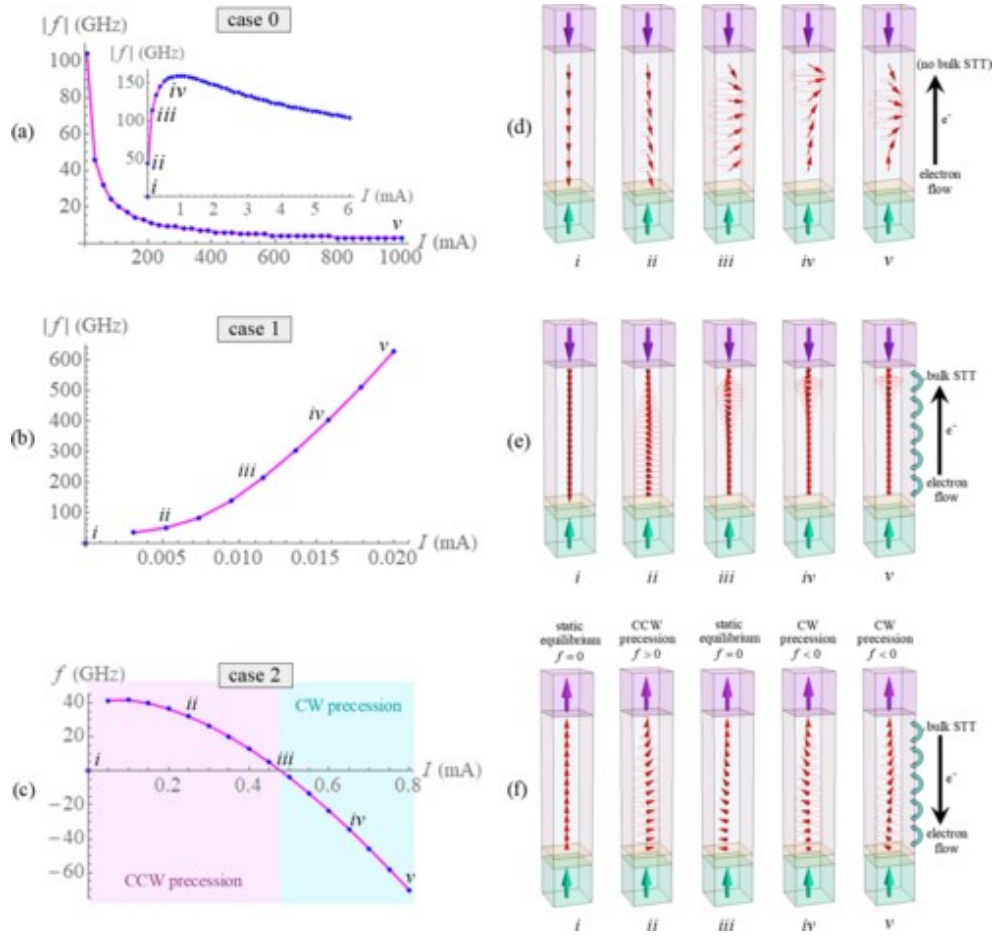

Individual spins and torques
i = N
1 < i < N
i = 1
(a)

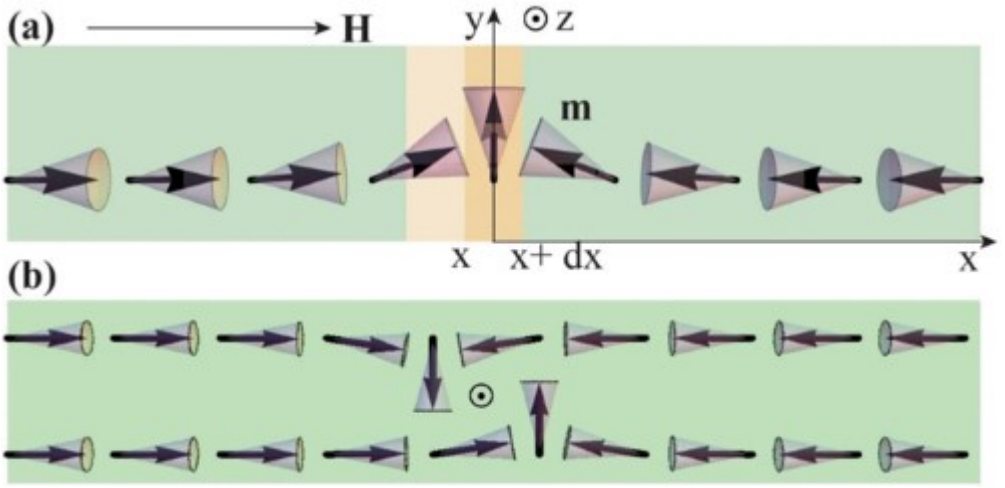

Net magnetic moment and torques
(b)

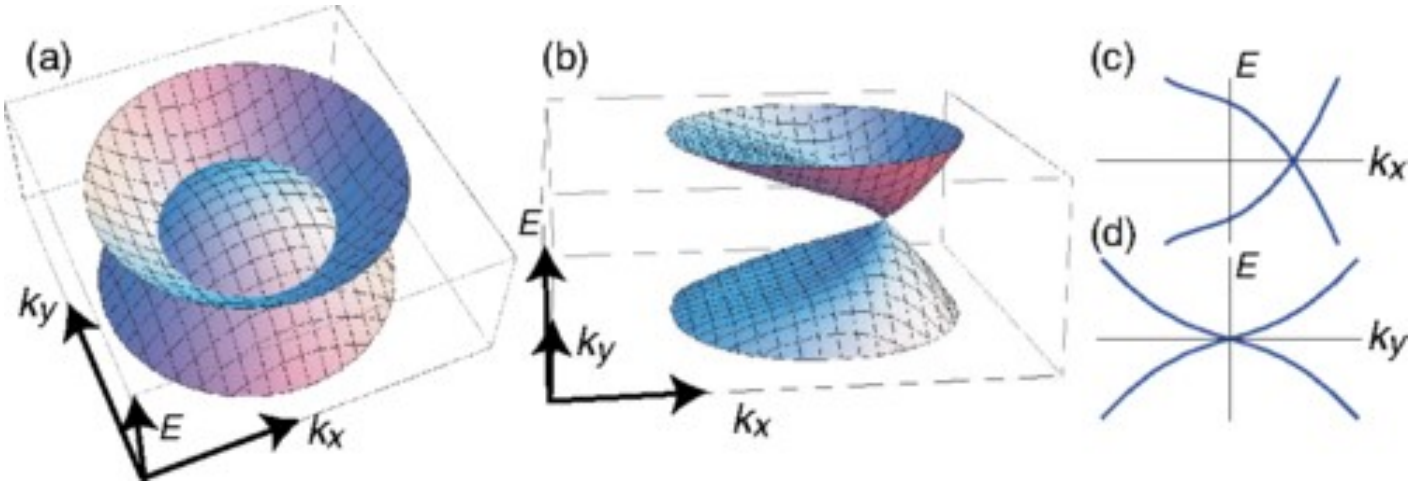

case 0
case 1
case 2
$I < I_0$
$I > I_0$
(no bulk STT)
bulk STT
electron flow
out of page
in page
CW clockwise
CCW counter-clockwise
schematic shadow showing twist
overhead view
case 0
case 1
case 2
$\phi_N - \phi_1$
I (mA)
$I = 1$ mA
$I = 0.01$ mA
$I = 0.03$ mA
CW
CCW
(a)
(b)
(c)
(d)
(e)
(f)

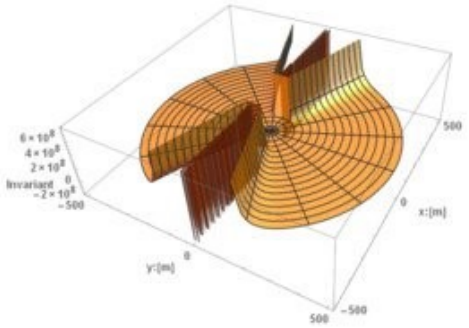

case 0
$I \to \infty$
(no bulk STT)
e⁻
electron flow
μ_{net}
T_{iSTT}
T_{damp}
T_{iex}
$T_{net} \to 0$
CW
$|T_{iex}| \approx |T_{iSTT}| \ll |T_{damp}|$
$T_{iex} + T_{iSTT} + T_{damp} = T_{net}$
overhead view


case 0
no bulk STT
case 1
with bulk STT
case 2
with bulk STT
pinned layer
exchange coupling
free layer
spacer
polarizer
(no bulk STT)
bulk STT
e⁻
electron flow
$i = N$
$i = N-1$
$i = 2$
$i = 1$
spin chain
coordinate system
$\hat{\mathbf{m}}_i$
θ_i
ϕ_i
x
y
z
(a)
(b)
(c)
(d)

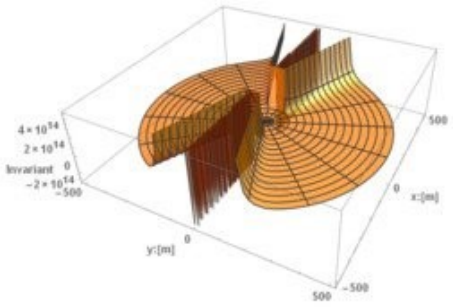

case 0
case 1
case 2
(a)
(b)
(c)
(d)
(e)
(f)
|f| (GHz)
f (GHz)
I (mA)
CW precession
CCW precession
(no bulk STT)
bulk STT
electron flow
static equilibrium f = 0
CCW precession f > 0
CW precession f < 0
i
ii
iii
iv
v


(a)
H
y
z
m
x
x+ dx
(b)

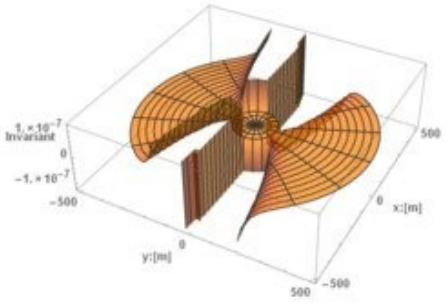

(a)
ky
E
kx
(b)
E
ky
kx
(c)
E
kx
(d)
E
ky



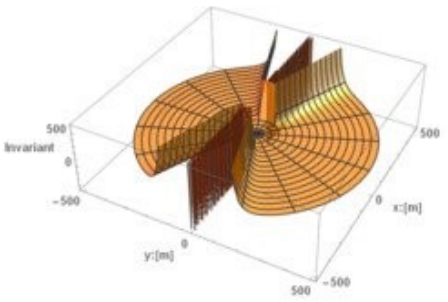
(**c**) r_2 and $t = 10$ s



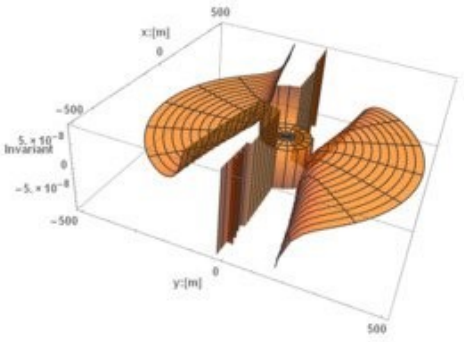
(**d**) r_2 and $t = 100$ s



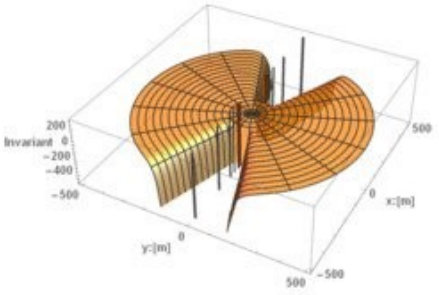
(**a**) r_2 and $t = 0.0$ s



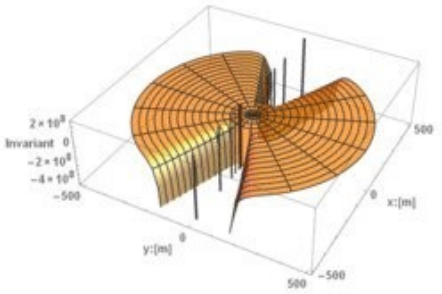
(**b**) r_2 and $t = 1$ s



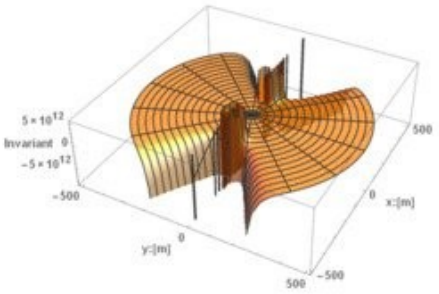
(**a**) w_2 and $t = 0$ s



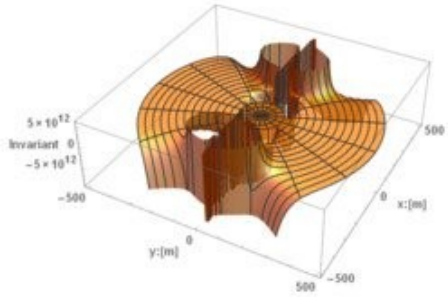
(**b**) w_2 and $t = 1.0$ s



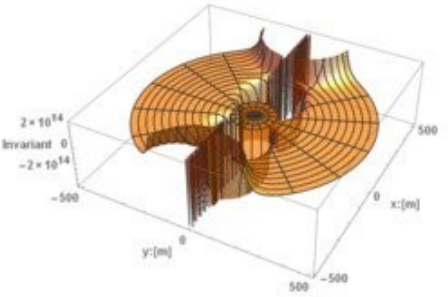
(**c**) w_2 and $t = 10.0$ s



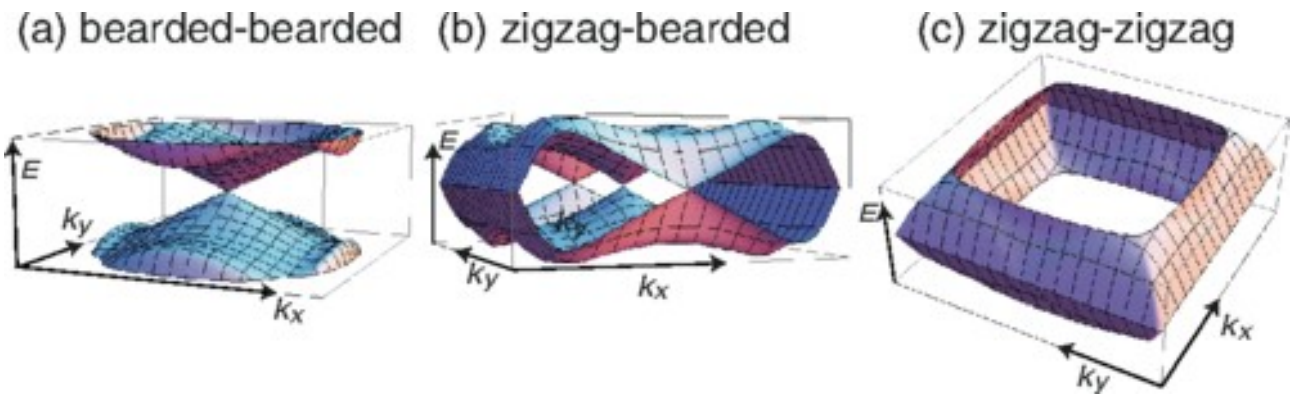
(**d**) w_2 and $t = 100.0$ s

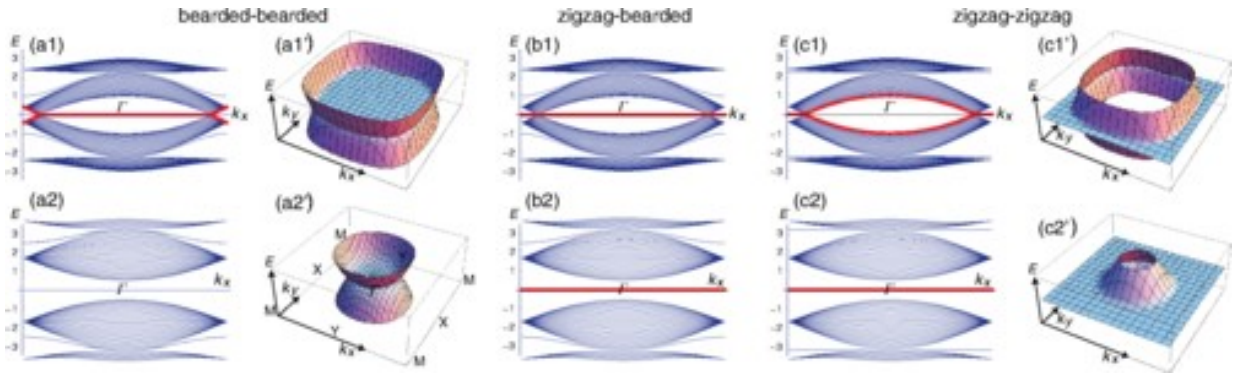


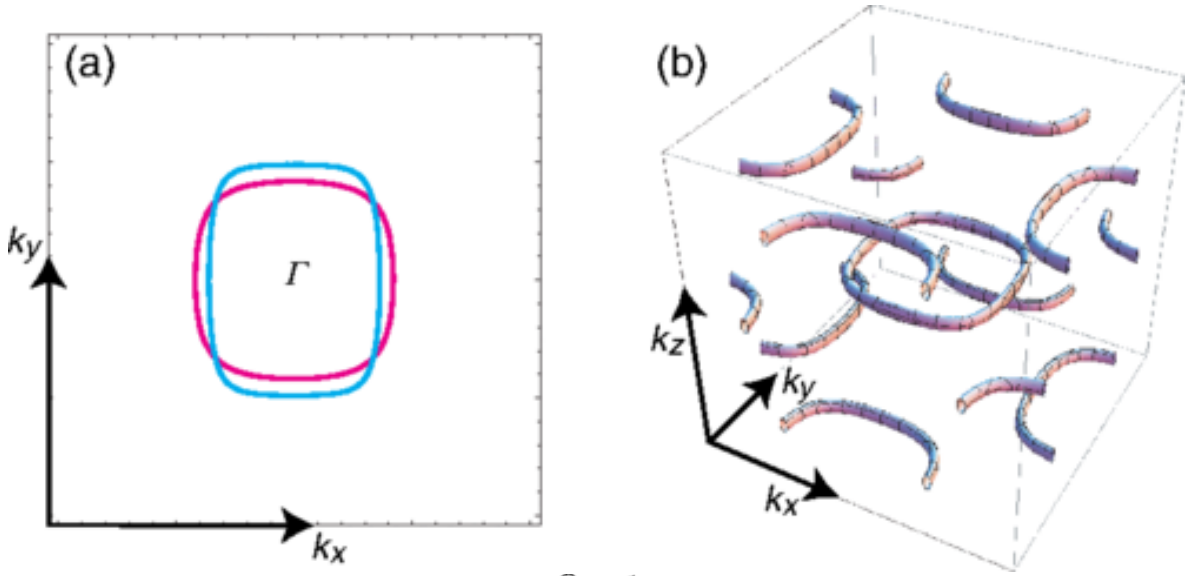
(**e**) w_2 and $t = 200.0$ s



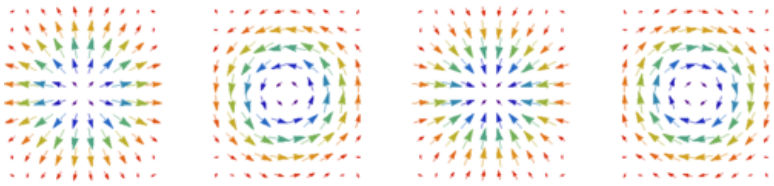
(**f**) w_2 and $t = 300.0$ s





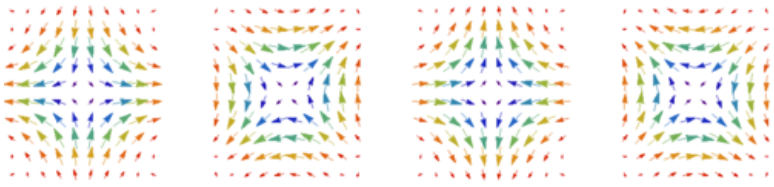


$Q = 1$

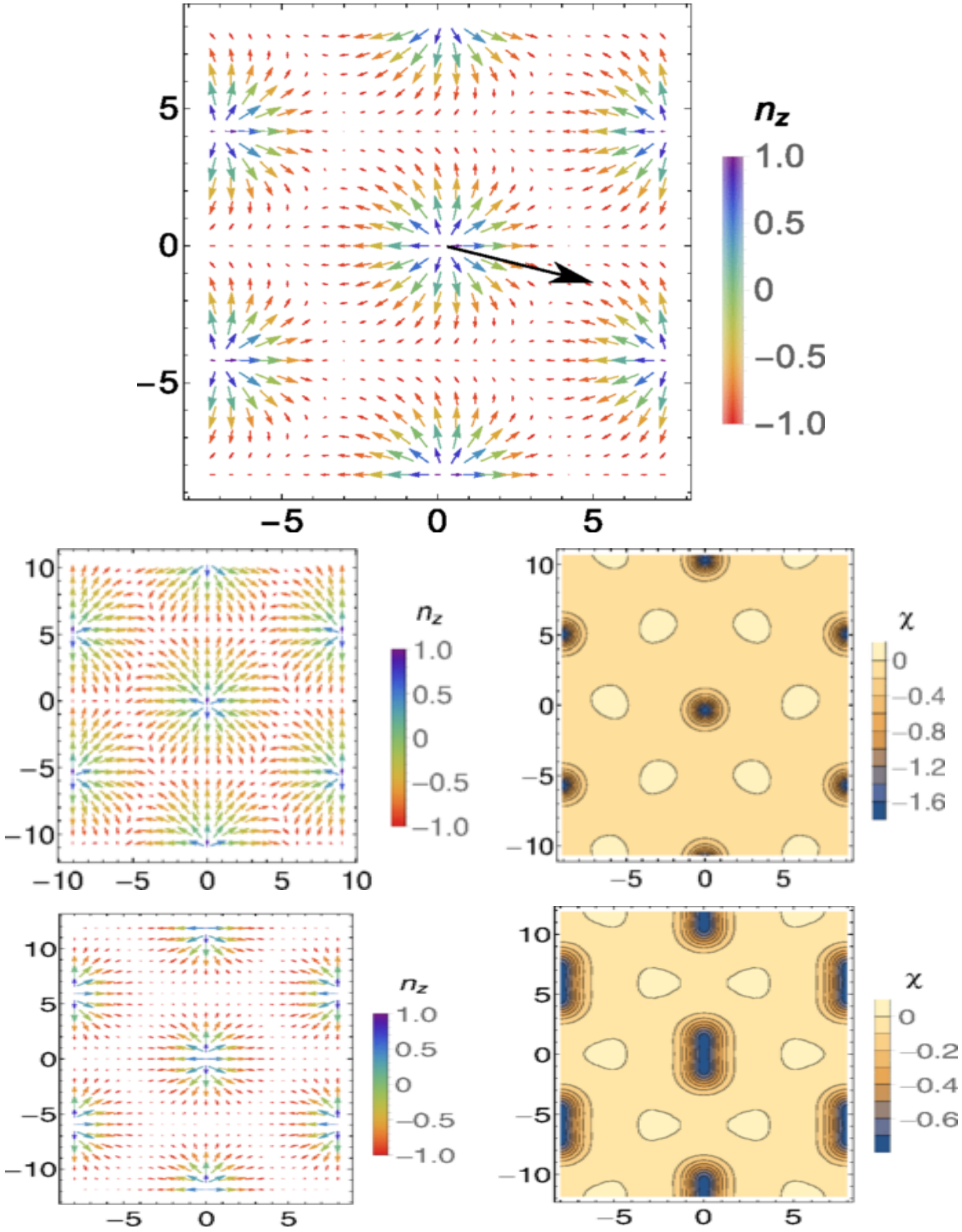


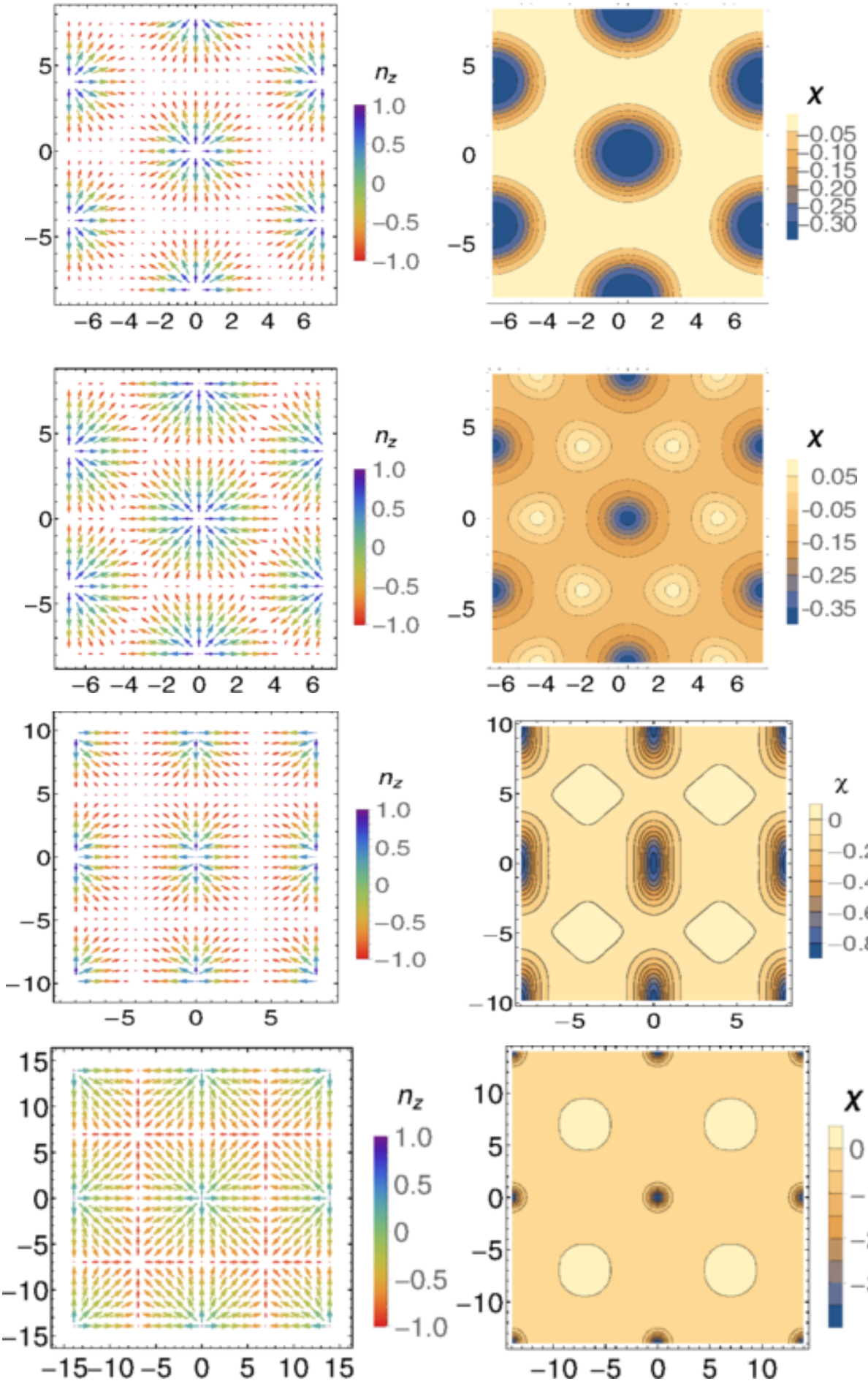
(a) $\gamma = 0$ (b) $\gamma = \frac{\pi}{2}$ (c) $\gamma = \pi$ (d) $\gamma = -\frac{\pi}{2}$

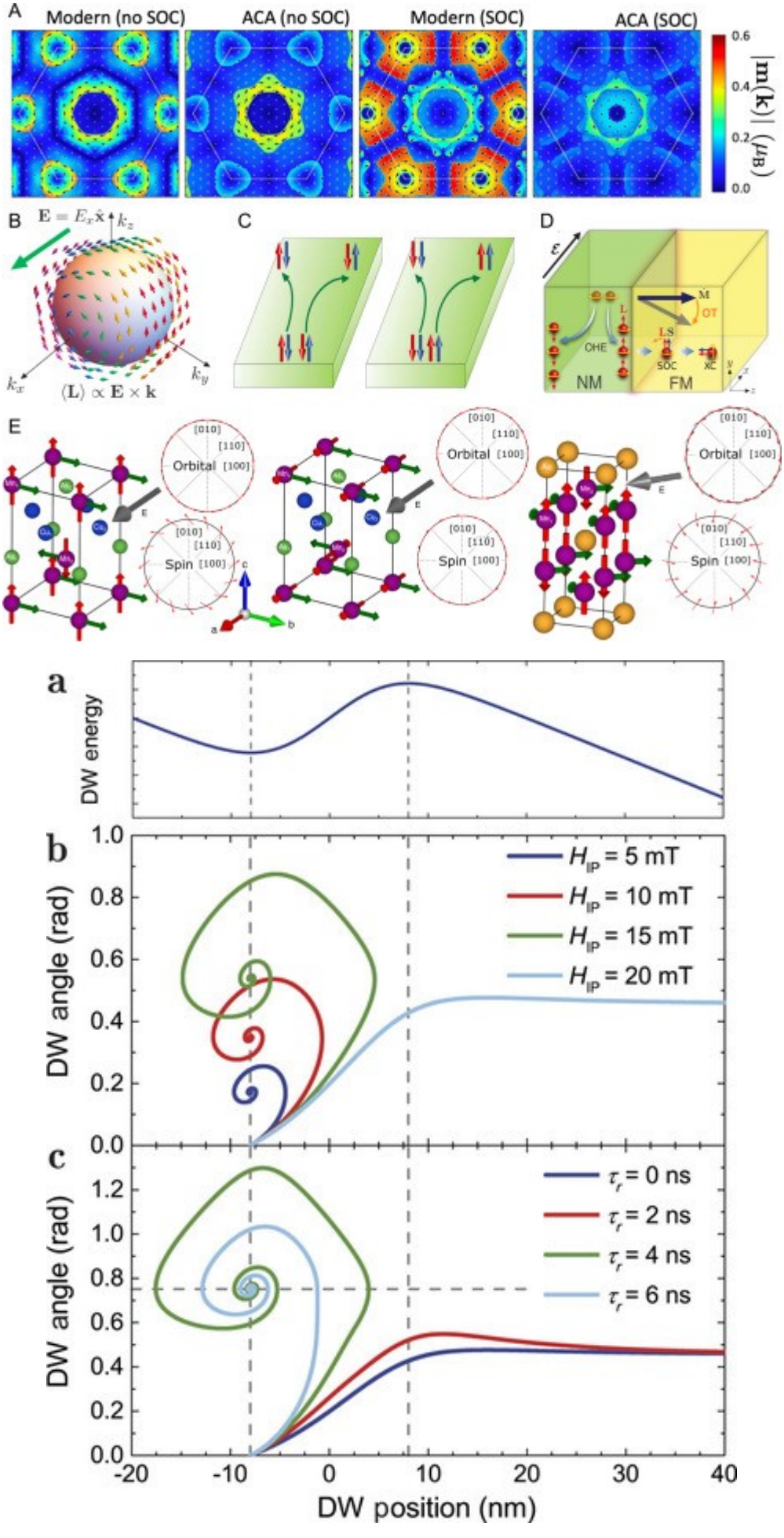
$Q = -1$

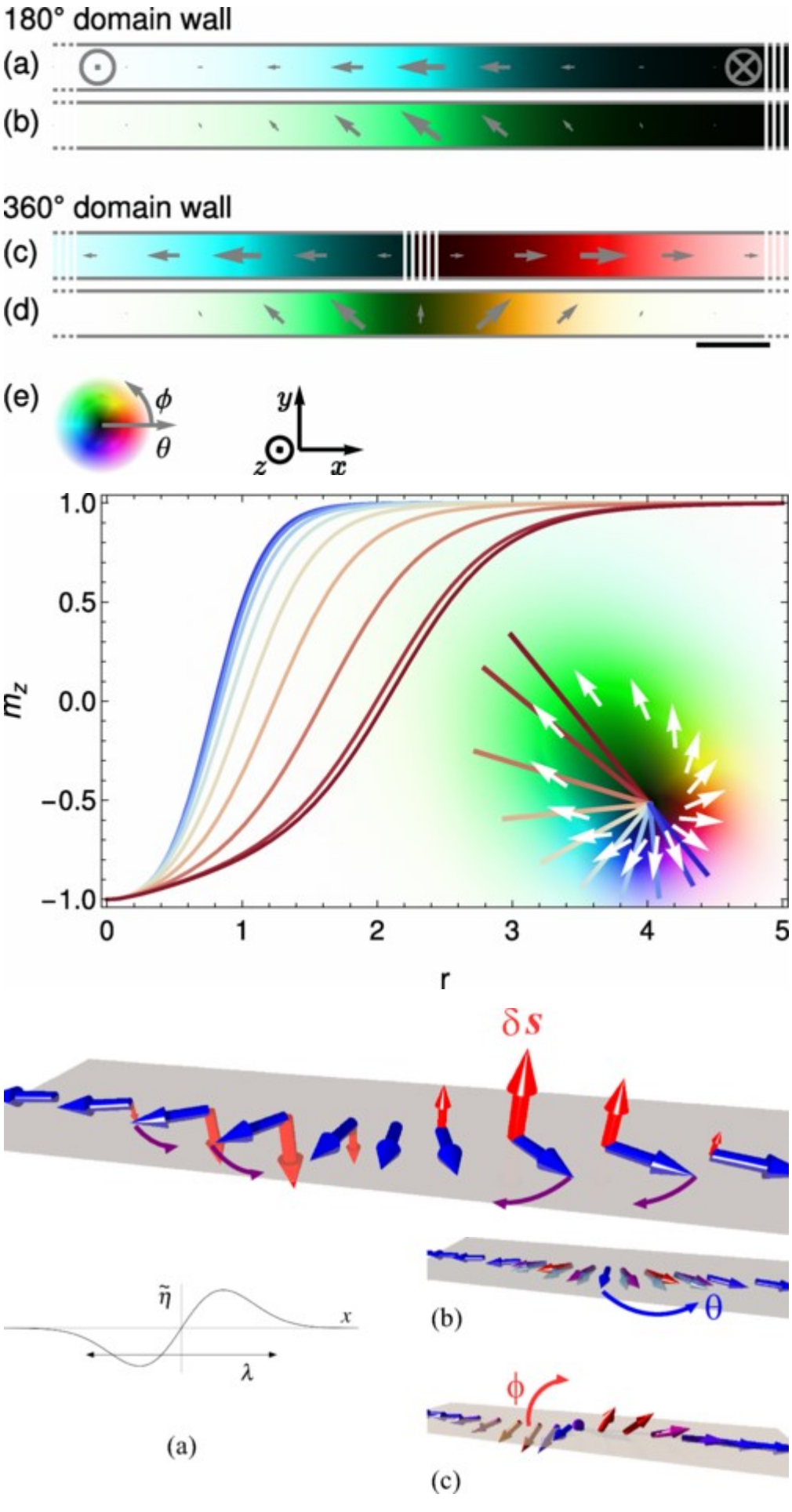


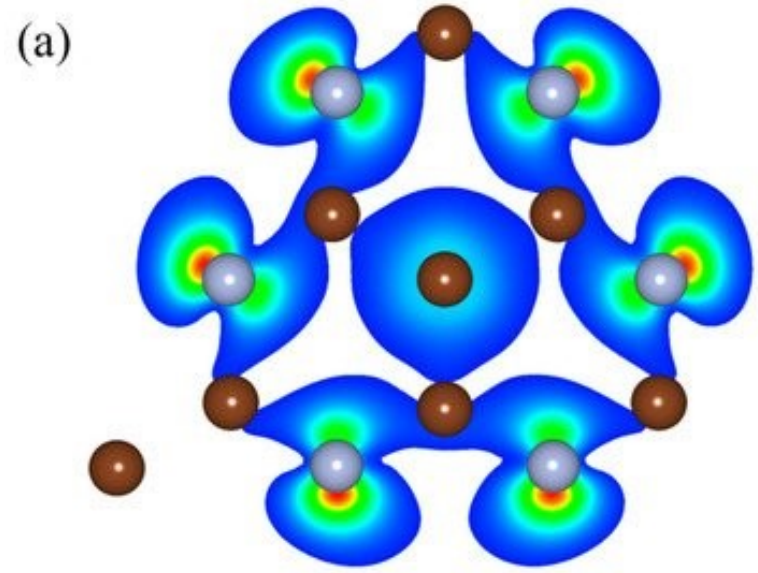
(e) $\gamma = 0$ (f) $\gamma = \frac{\pi}{2}$ (g) $\gamma = \pi$ (h) $\gamma = -\frac{\pi}{2}$

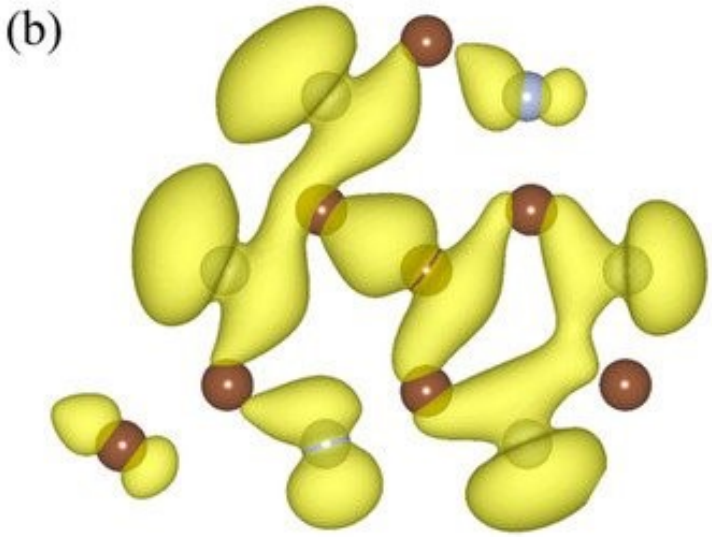

n_z
1.0
0.5
0
−0.5
−1.0
5
0
−5
−5
0
5
n_z
1.0
0.5
0
−0.5
−1.0
10
5
0
−5
−10
−10
−5
0
5
10
χ
0
−0.4
−0.8
−1.2
−1.6
10
5
0
−5
−10
−5
0
5
n_z
1.0
0.5
0
−0.5
−1.0
10
5
0
−5
−10
−5
0
5
χ
0
−0.2
−0.4
−0.6
10
5
0
−5
−10
−5
0
5

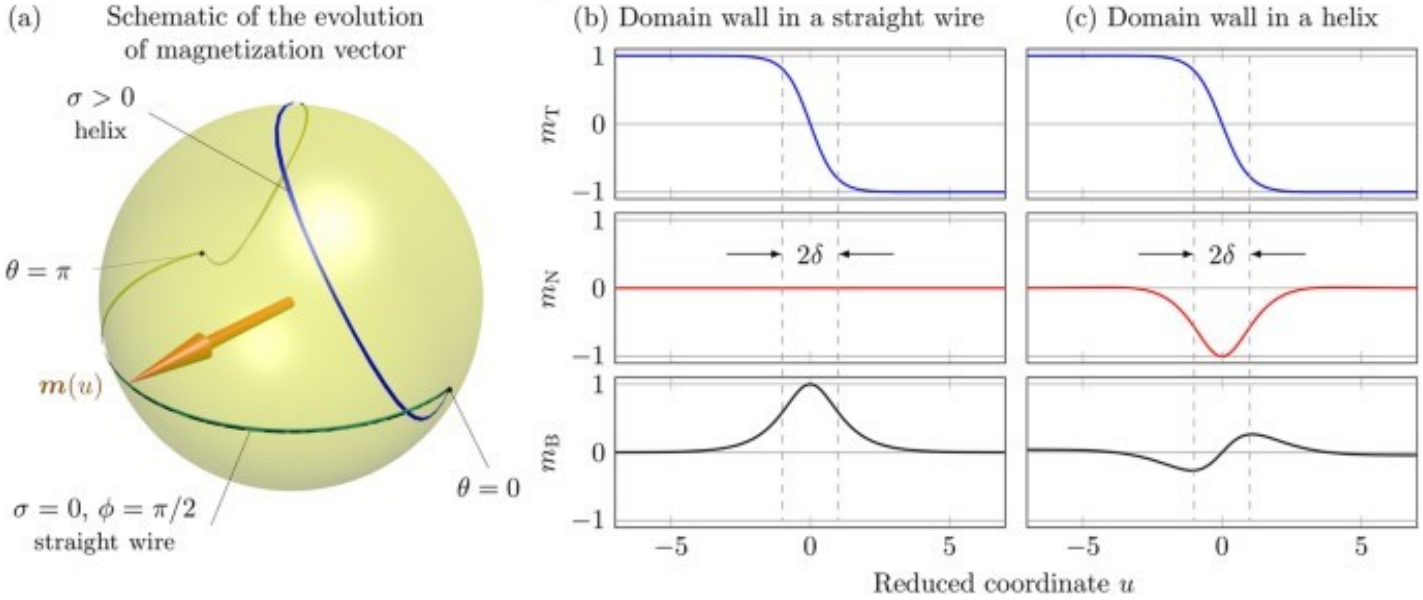

n_z
1.0
0.5
0
−0.5
−1.0
χ
−0.05
−0.10
−0.15
−0.20
−0.25
−0.30
0.05
−0.35
−0.2
−0.4
−0.6
−0.8
−1
−2
−3

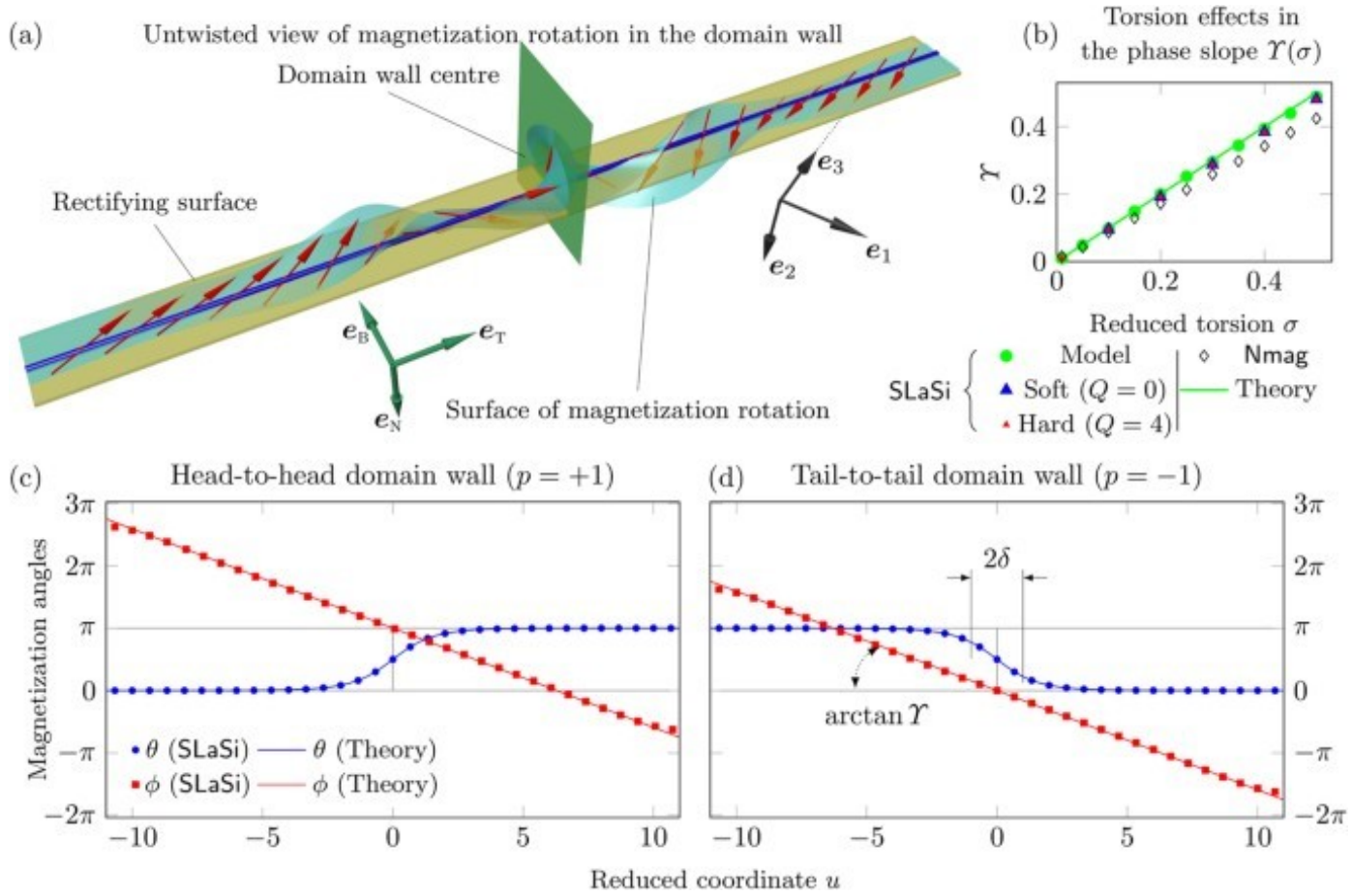

A
Modern (no SOC)
ACA (no SOC)
Modern (SOC)
ACA (SOC)
0.6
0.4
0.2
0.0
|m(k)| (μB)
B
$\mathbf{E} = E_x\hat{\mathbf{x}}$
k_z
k_x
k_y
$\langle \mathbf{L} \rangle \propto \mathbf{E} \times \mathbf{k}$
C
D
ε
M
OT
L
LS
OHE
SOC
XC
NM
FM
E
[010]
[110]
Orbital [100]
Spin [100]
c
a
b
a
DW energy
b
DW angle (rad)
1.0
0.8
0.6
0.4
0.2
0.0
H_{IP} = 5 mT
H_{IP} = 10 mT
H_{IP} = 15 mT
H_{IP} = 20 mT
c
DW angle (rad)
1.2
1.0
0.8
0.6
0.4
0.2
0.0
τ_r = 0 ns
τ_r = 2 ns
τ_r = 4 ns
τ_r = 6 ns
-20
-10
0
10
20
30
40
DW position (nm)

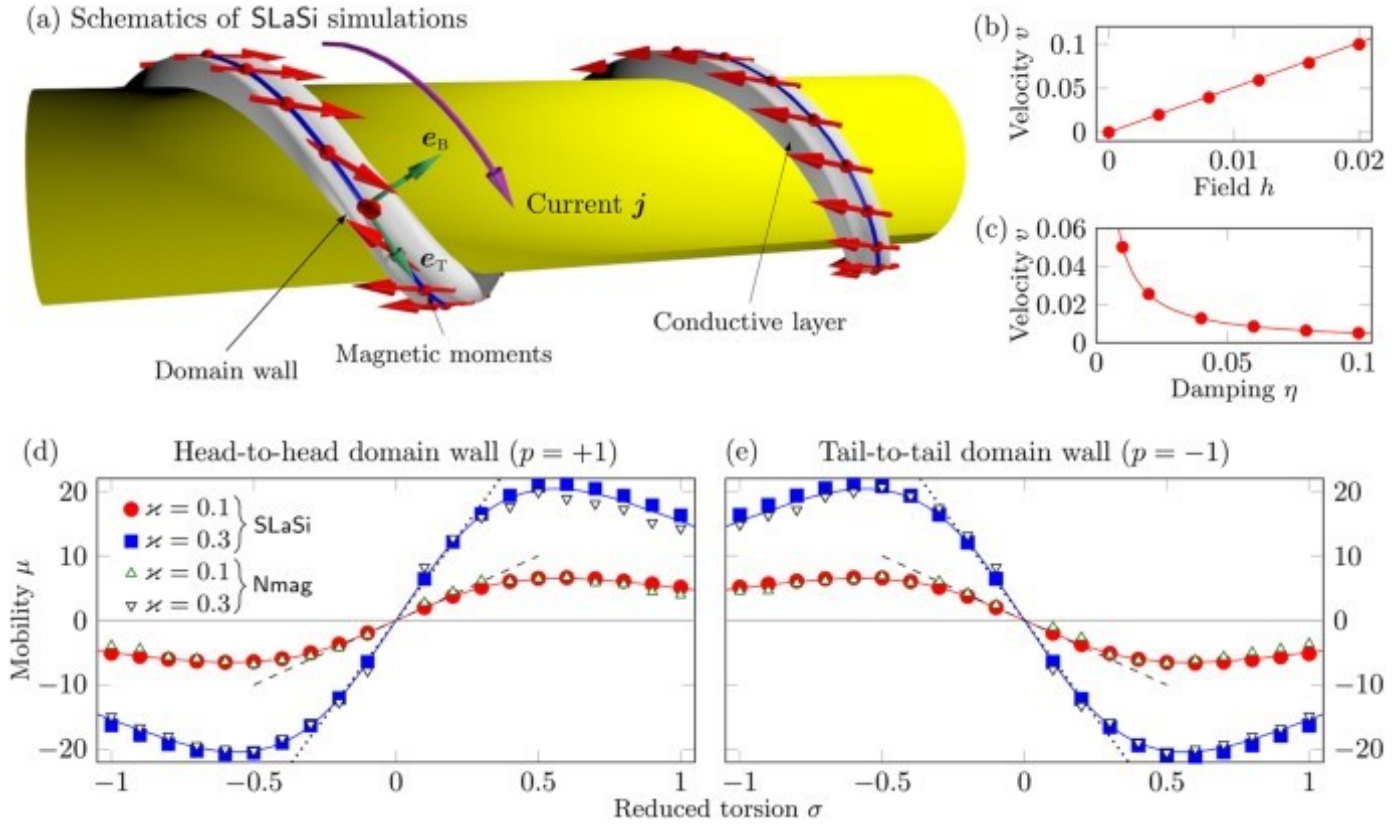

180° domain wall
(a)
(b)
360° domain wall
(c)
(d)
(e)
ϕ
θ
y
z
x
1.0
0.5
0.0
−0.5
−1.0
m_z
0
1
2
3
4
5
r
δs
θ
ϕ
(a)
(b)
(c)

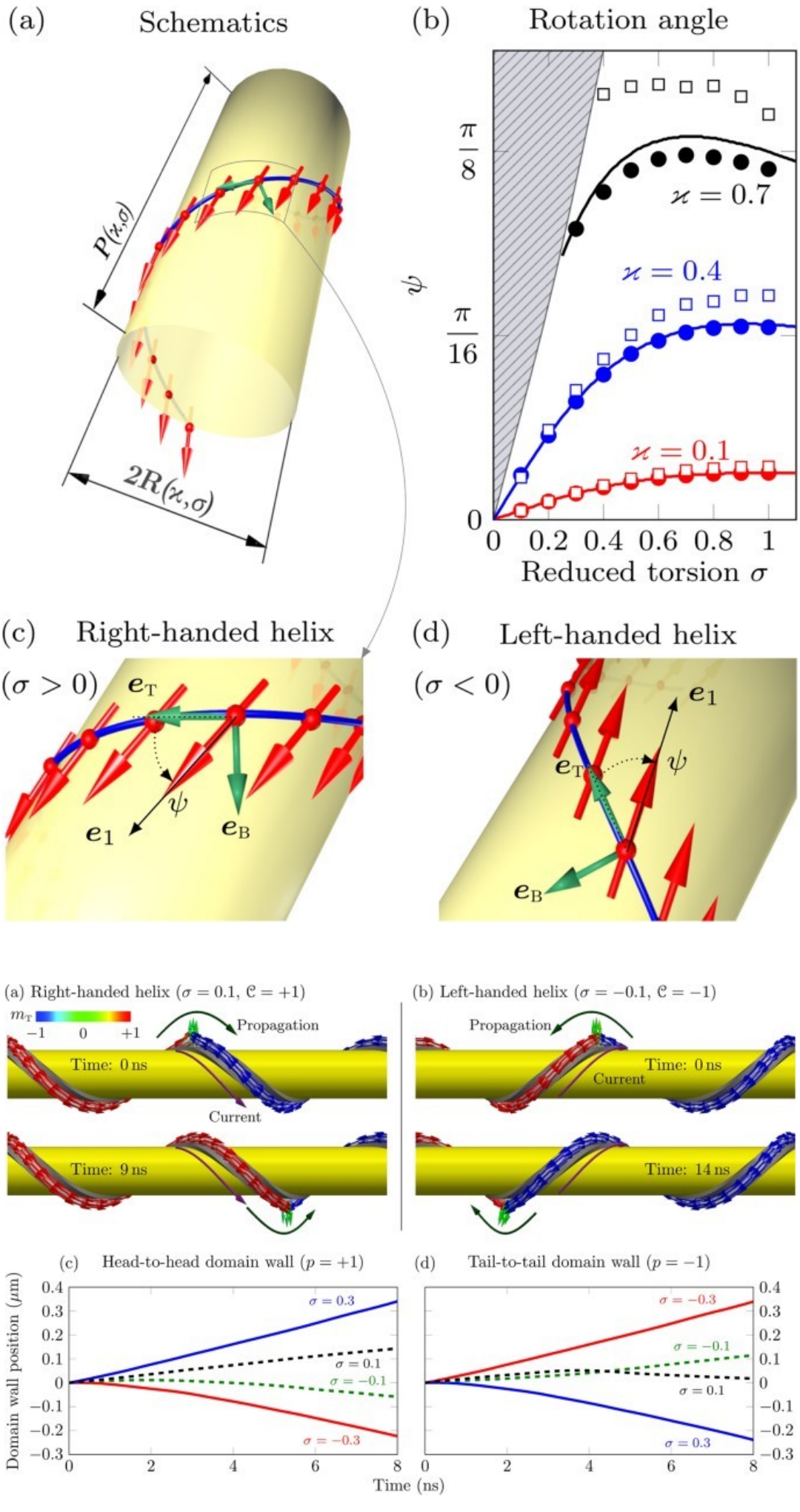

(a)

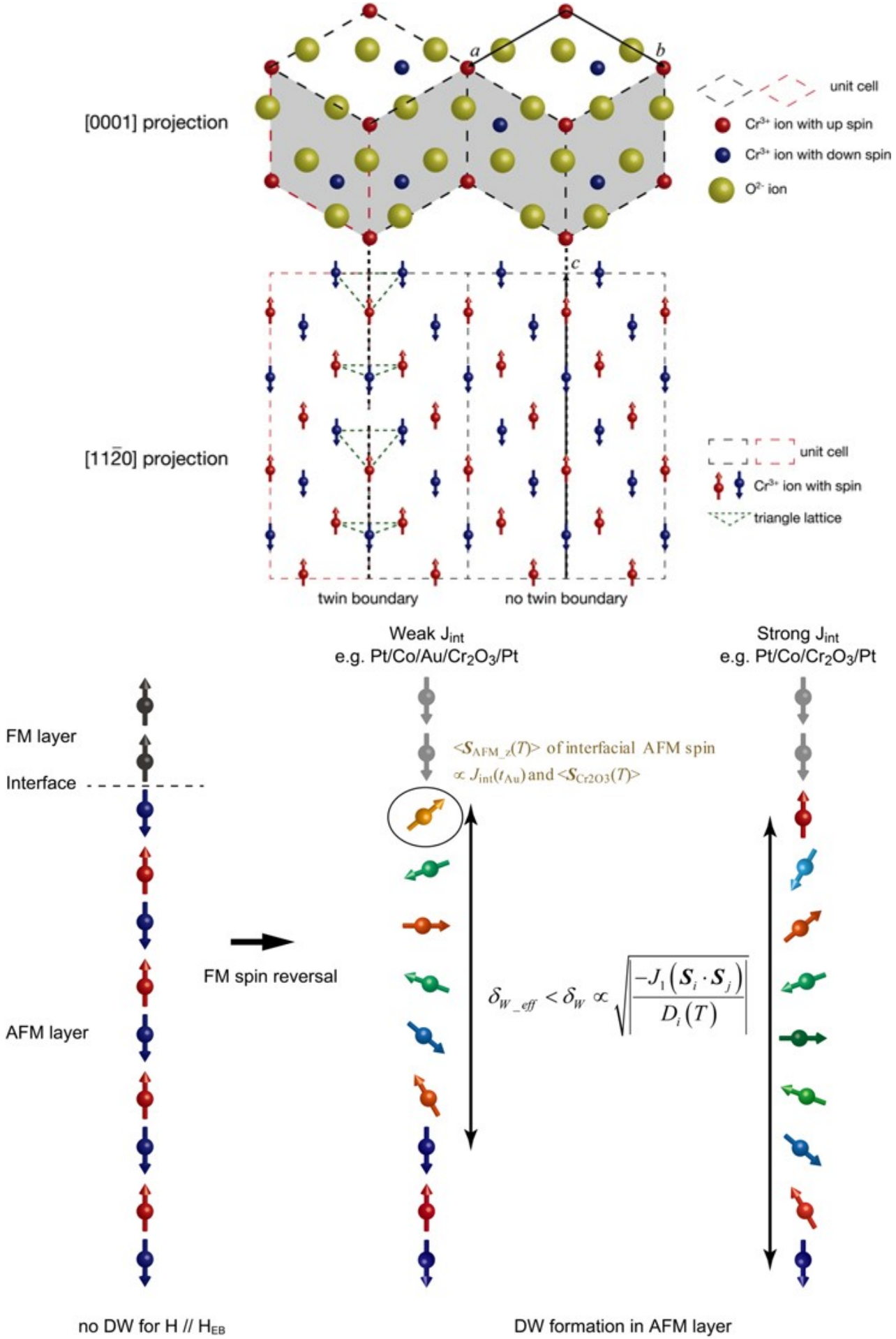

(b)

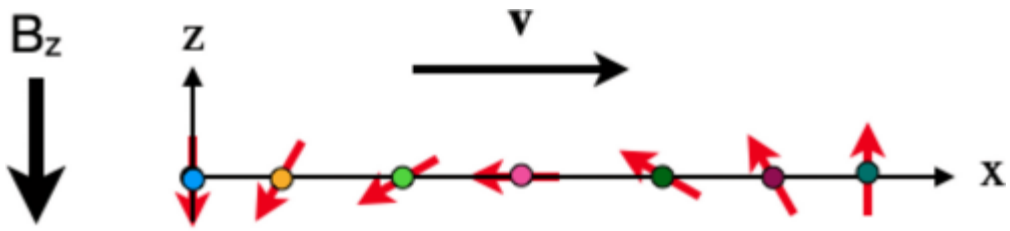

(a) Schematic of the evolution of magnetization vector
$\sigma > 0$ helix
$\theta = \pi$
$m(u)$
$\theta = 0$
$\sigma = 0, \phi = \pi/2$ straight wire
(b) Domain wall in a straight wire
(c) Domain wall in a helix
m_T
m_N
m_B
2δ
2δ
1
0
−1
−5
0
5
Reduced coordinate u

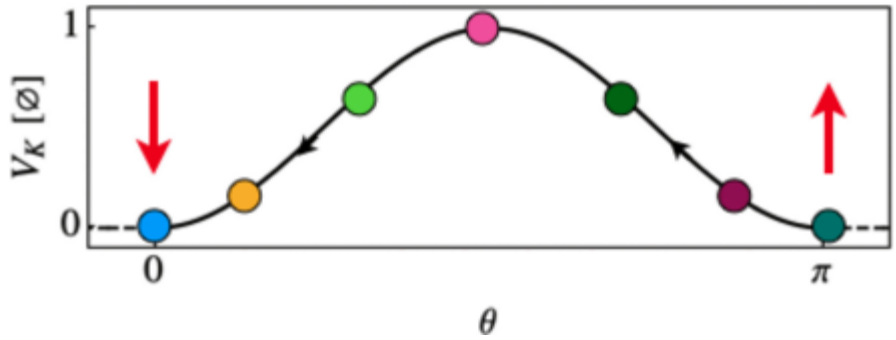

(a)
Untwisted view of magnetization rotation in the domain wall
Domain wall centre
Rectifying surface
e_3
e_1
e_2
e_B
e_T
e_N
Surface of magnetization rotation
(b)
Torsion effects in the phase slope $\Upsilon(\sigma)$
Υ
Reduced torsion σ
SLaSi
Model
Soft ($Q = 0$)
Hard ($Q = 4$)
Nmag
Theory
(c)
Head-to-head domain wall ($p = +1$)
(d)
Tail-to-tail domain wall ($p = -1$)
Magnetization angles
2δ
$\arctan \Upsilon$
θ (SLaSi)
θ (Theory)
ϕ (SLaSi)
ϕ (Theory)
Reduced coordinate u

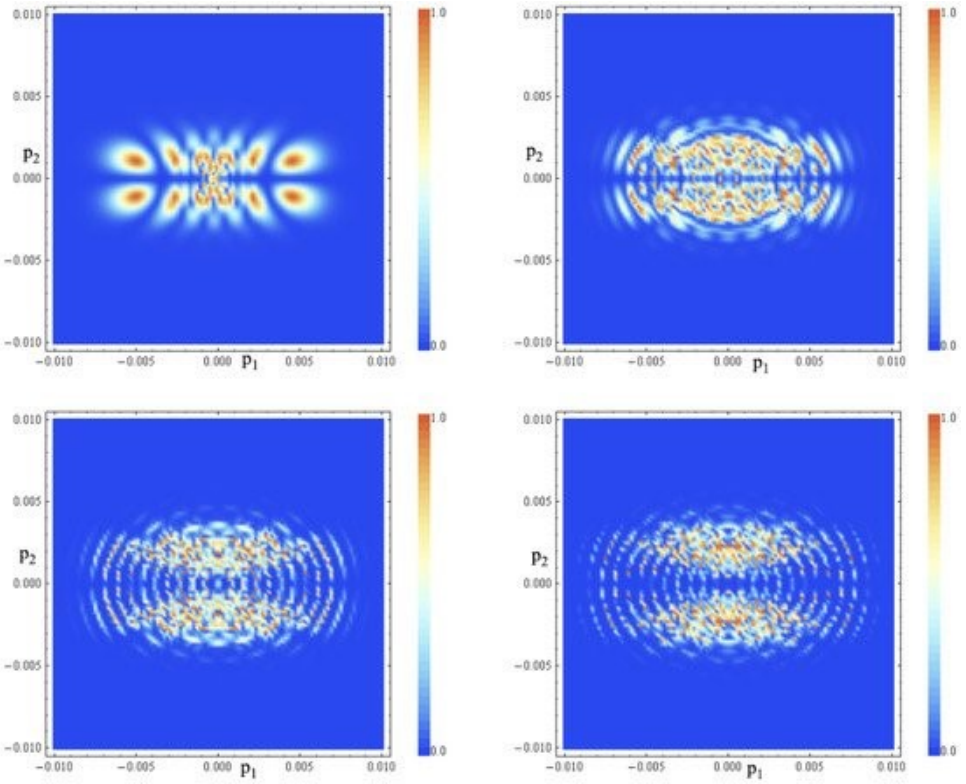

(a) Schematics of SLaSi simulations
e_B
e_T
Current j
Domain wall
Magnetic moments
Conductive layer
(b)
Velocity v
Field h
(c)
Velocity v
Damping η
(d)
Head-to-head domain wall ($p = +1$)
(e)
Tail-to-tail domain wall ($p = -1$)
$\varkappa = 0.1$
$\varkappa = 0.3$
SLaSi
Nmag
Mobility μ
Reduced torsion σ


(a) Schematics
P(κ,σ)
2R(κ,σ)
(b) Rotation angle
π/8
π/16
0
ψ
κ = 0.7
κ = 0.4
κ = 0.1
0 0.2 0.4 0.6 0.8 1
Reduced torsion σ
(c) Right-handed helix
(σ > 0)
e_T
ψ
e_1
e_B
(d) Left-handed helix
(σ < 0)
e_1
e_T
ψ
e_B
(a) Right-handed helix (σ = 0.1, ℭ = +1)
m_T
−1 0 +1
Propagation
Time: 0 ns
Current
Time: 9 ns
(b) Left-handed helix (σ = −0.1, ℭ = −1)
Propagation
Time: 0 ns
Current
Time: 14 ns
(c) Head-to-head domain wall (p = +1)
(d) Tail-to-tail domain wall (p = −1)
Domain wall position (μm)
σ = 0.3
σ = 0.1
σ = −0.1
σ = −0.3
Time (ns)

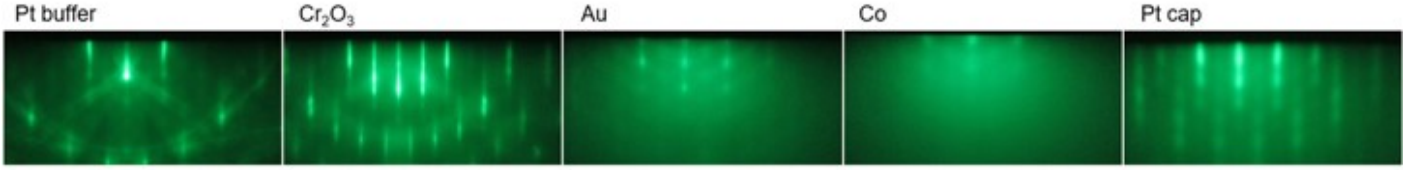

[0001] projection
a
b
c
unit cell
Cr3+ ion with up spin
Cr3+ ion with down spin
O2- ion
[11$\bar{2}$0] projection
unit cell
Cr3+ ion with spin
triangle lattice
twin boundary
no twin boundary
Weak Jint
e.g. Pt/Co/Au/Cr2O3/Pt
Strong Jint
e.g. Pt/Co/Cr2O3/Pt
FM layer
Interface
AFM layer
FM spin reversal
<SAFM_z(T)> of interfacial AFM spin
∝ Jint(tAu) and <SCr2O3(T)>
δW_eff < δW ∝ √(|−J1(Si · Sj) / Di(T)|)
no DW for H // HEB
DW formation in AFM layer



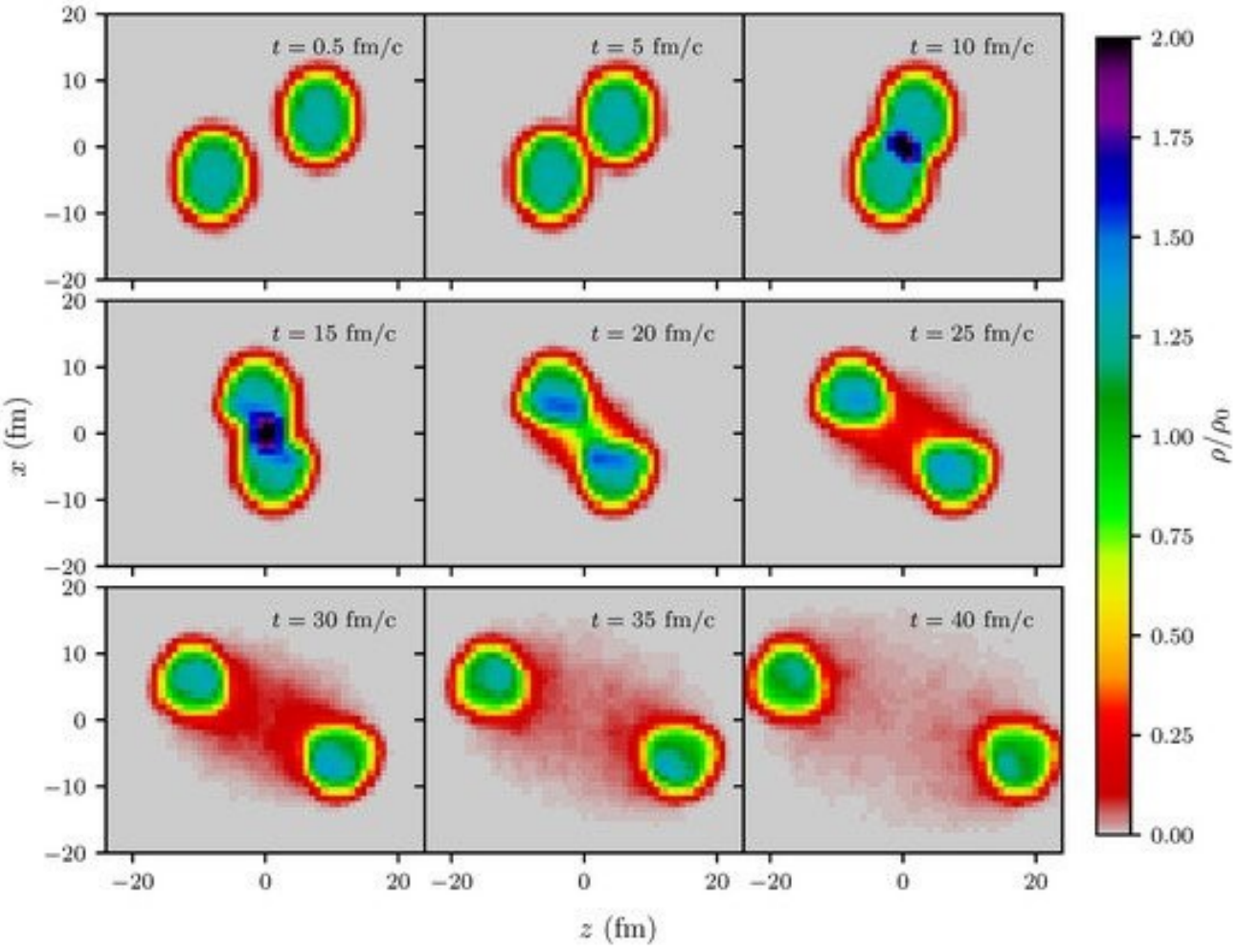


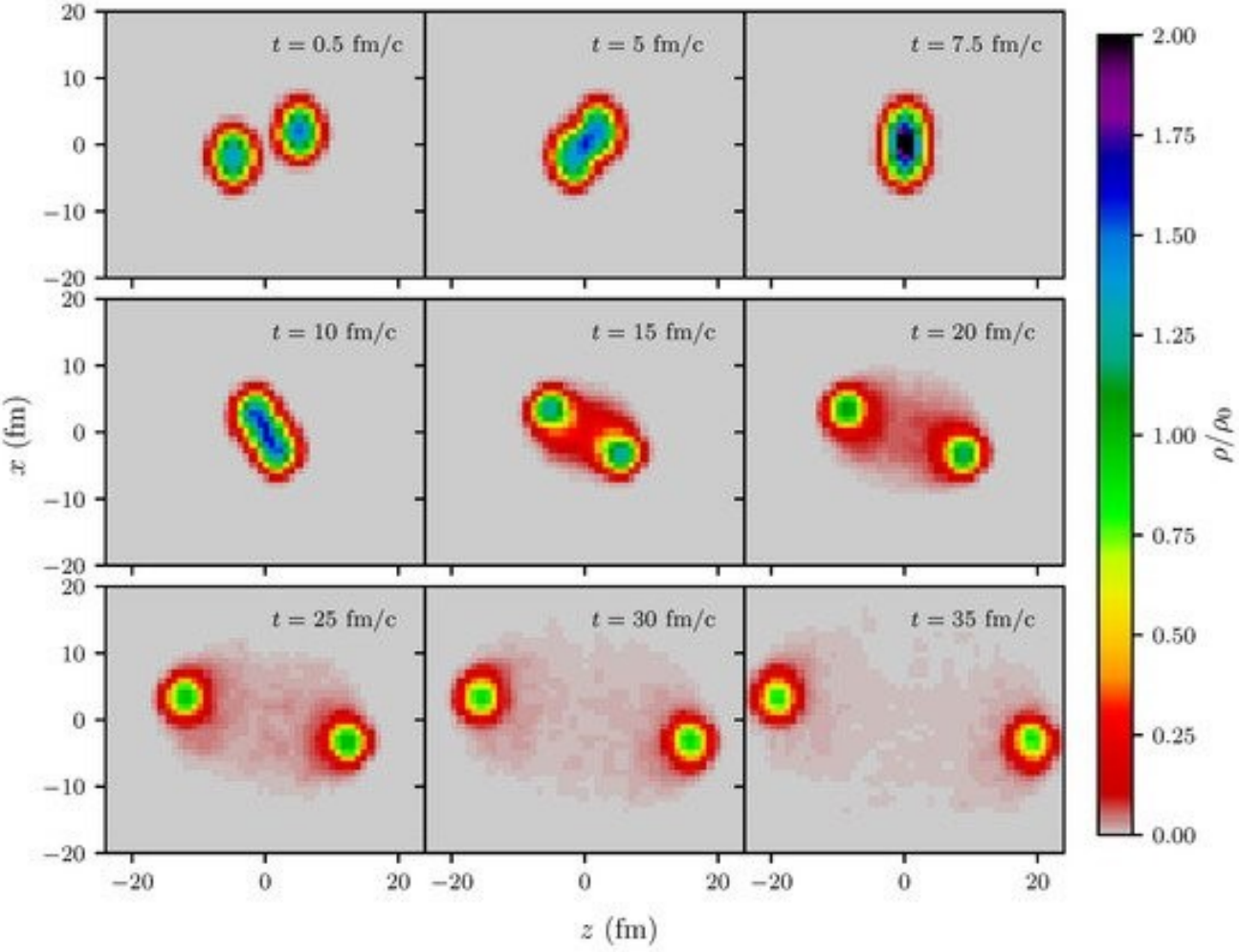


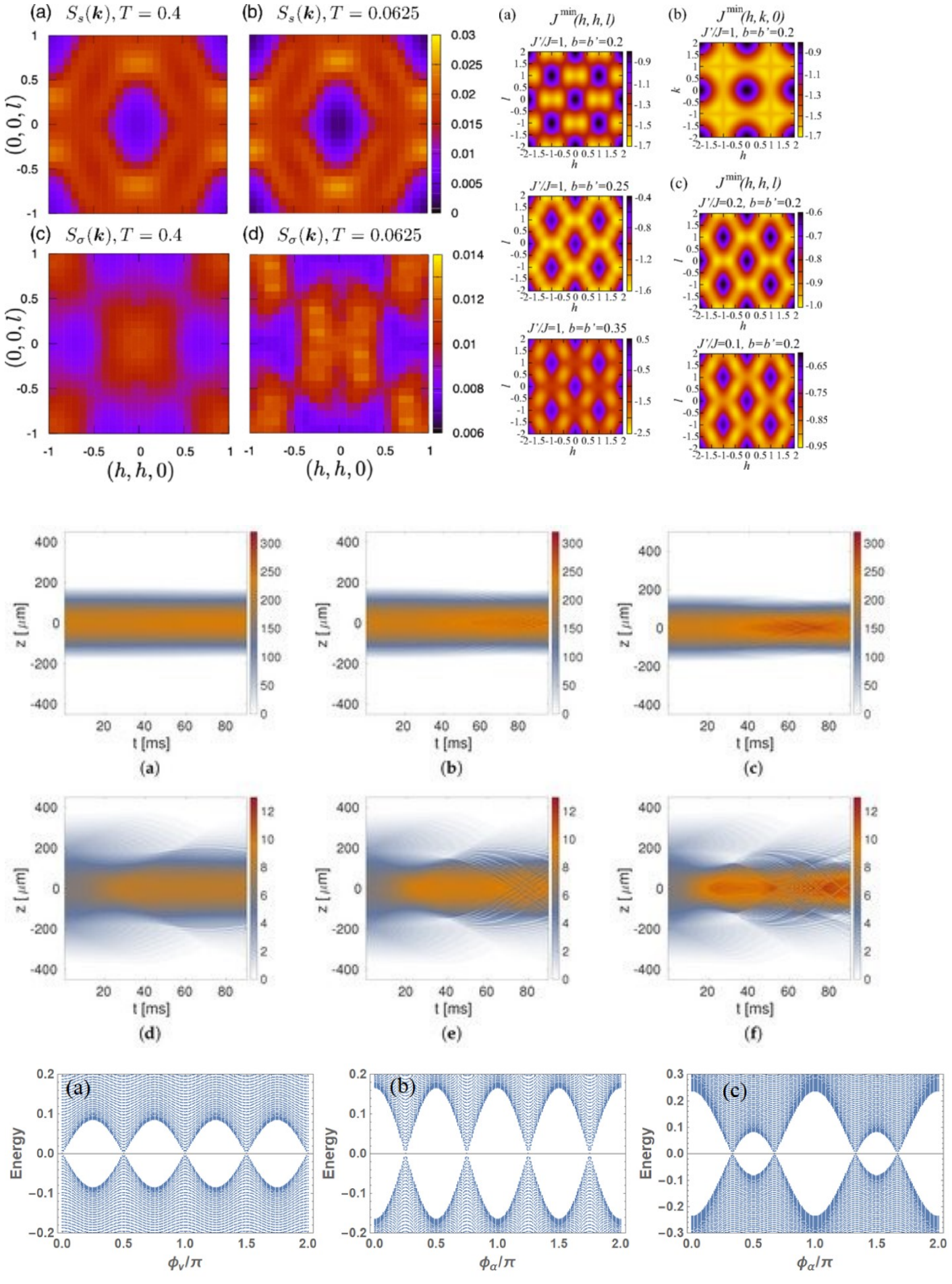
(a) <$1\bar{1}00$>$_{substrate}$-azimuth

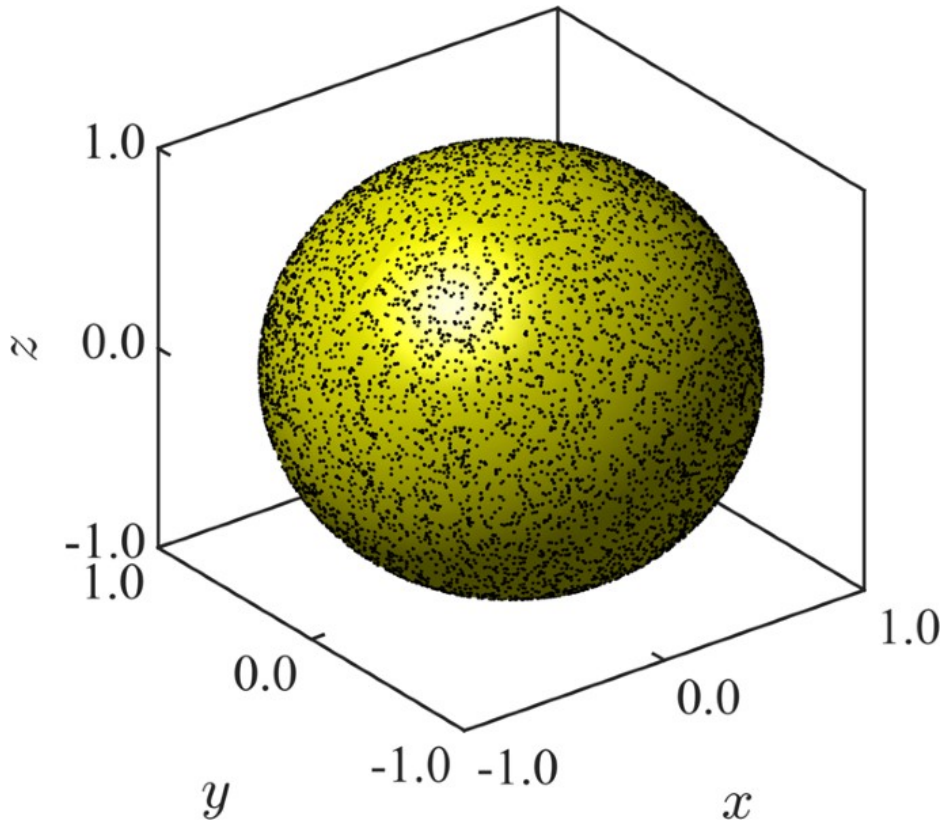


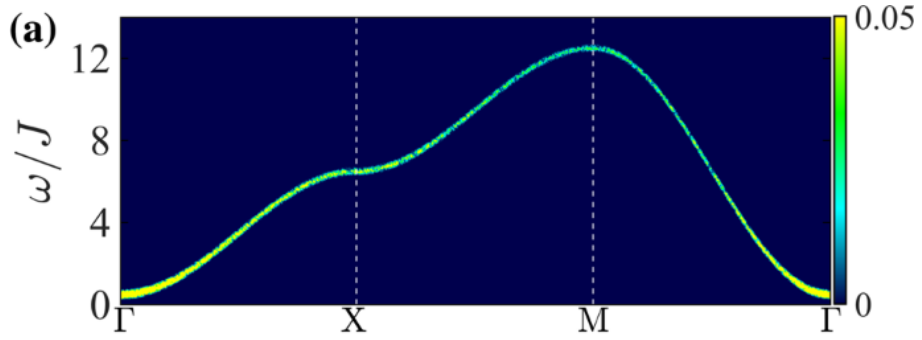
(b) <$11\bar{2}0$>$_{substrate}$-azimuth

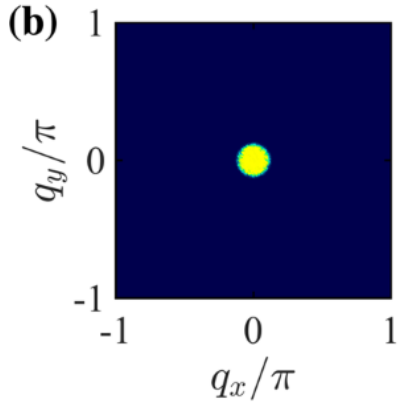

t = 0.5 fm/c
t = 5 fm/c
t = 10 fm/c
t = 15 fm/c
t = 20 fm/c
t = 25 fm/c
t = 30 fm/c
t = 35 fm/c
t = 40 fm/c
x (fm)
z (fm)
ρ/ρ0
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00

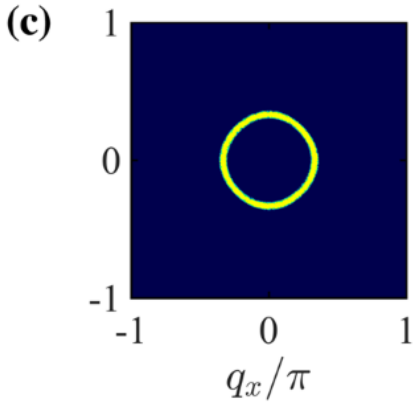

t = 0.5 fm/c
t = 5 fm/c
t = 7.5 fm/c
t = 10 fm/c
t = 15 fm/c
t = 20 fm/c
t = 25 fm/c
t = 30 fm/c
t = 35 fm/c
x (fm)
z (fm)
ρ/ρ0
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00

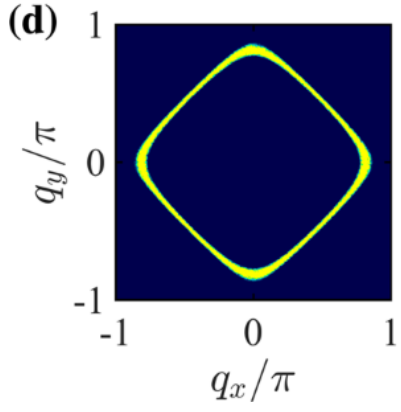

(a) $S_s(\boldsymbol{k}), T = 0.4$
(b) $S_s(\boldsymbol{k}), T = 0.0625$
(c) $S_\sigma(\boldsymbol{k}), T = 0.4$
(d) $S_\sigma(\boldsymbol{k}), T = 0.0625$
$(0, 0, l)$
$(h, h, 0)$
(a) $J^{\min}(h, h, l)$
(b) $J^{\min}(h, k, 0)$
(c) $J^{\min}(h, h, l)$
J'/J=1, b=b'=0.2
J'/J=1, b=b'=0.25
J'/J=1, b=b'=0.35
J'/J=0.2, b=b'=0.2
J'/J=0.1, b=b'=0.2
z [μm]
t [ms]
(a)
(b)
(c)
(d)
(e)
(f)
Energy
(a)
(b)
(c)
ϕ_v/π
ϕ_α/π
ϕ_α/π

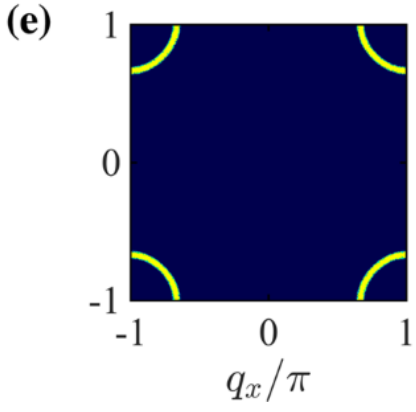

1.0
0.0
-1.0
z
1.0
0.0
-1.0
y
1.0
0.0
-1.0
x

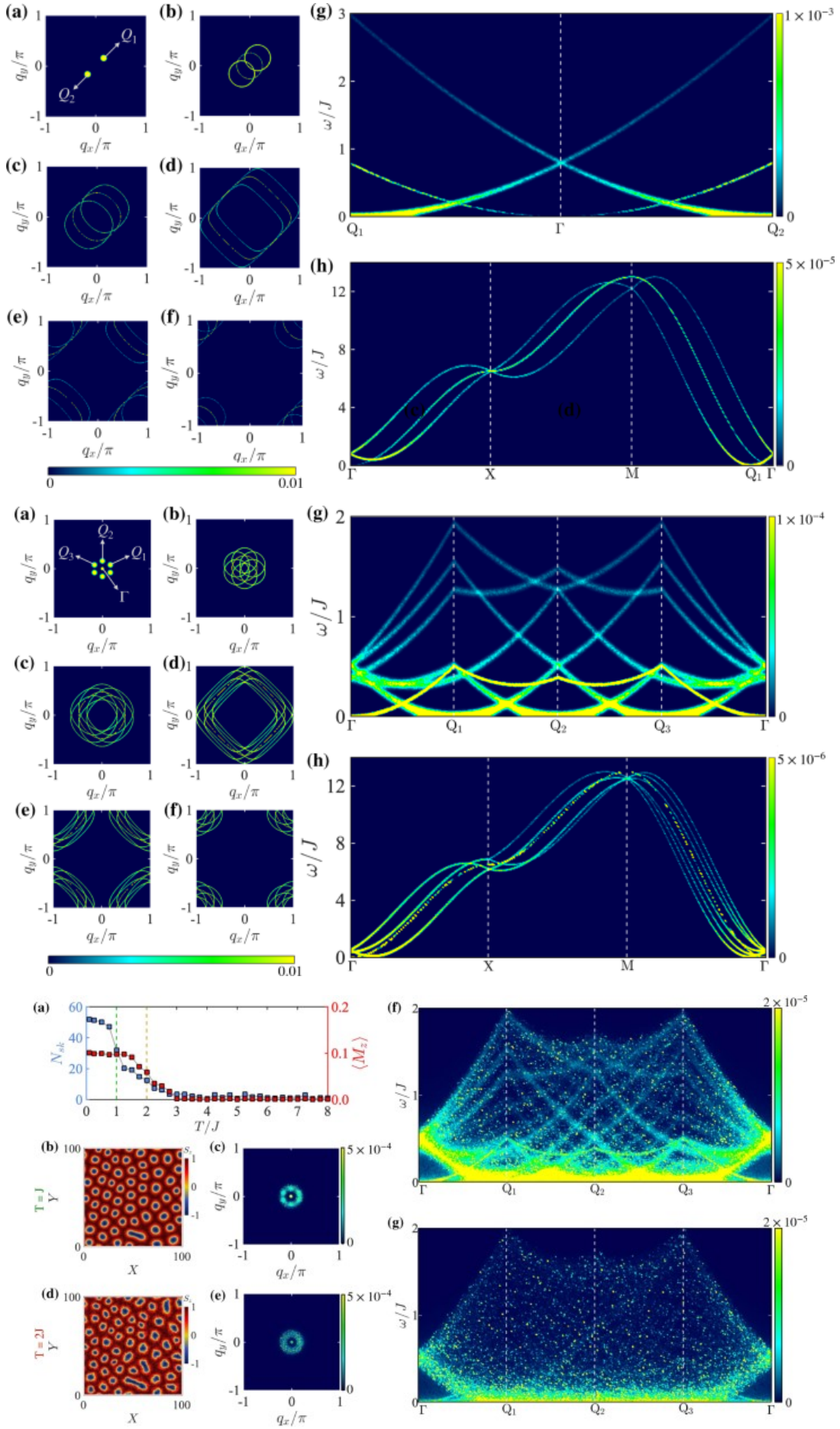

(a)
12
8
4
0
ω/J
Γ
X
M
Γ
0.05
0

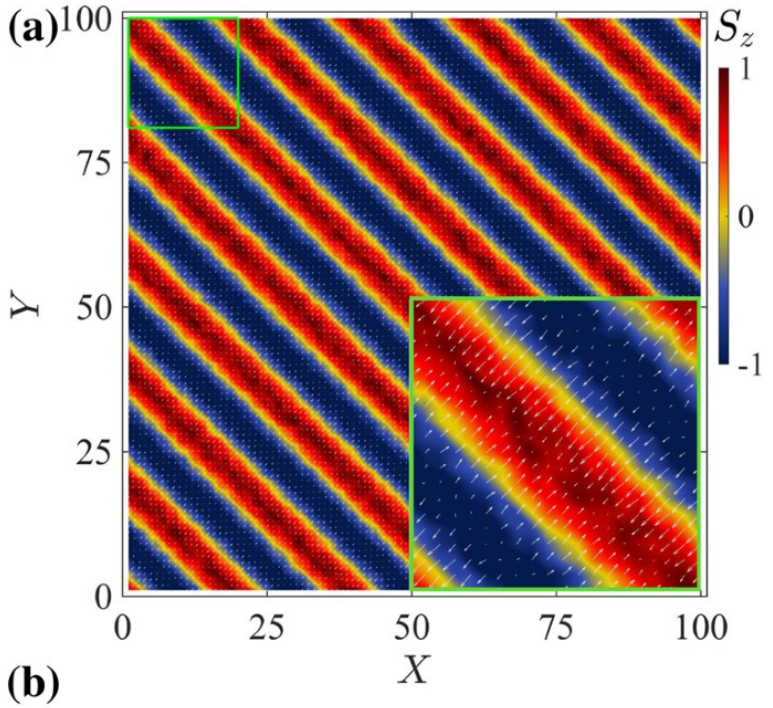

(b)
1
0
-1
q_y/π
-1
0
1
q_x/π

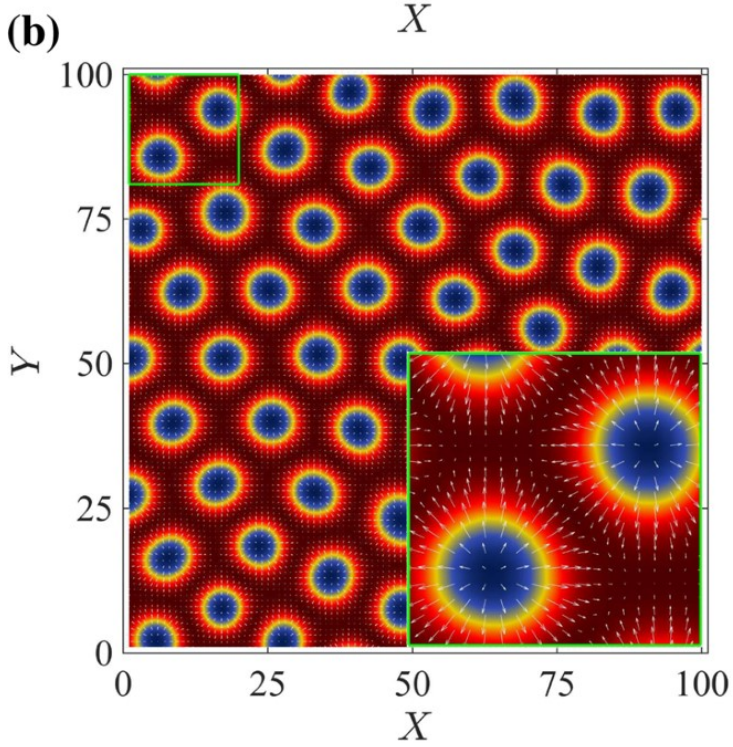

(c)
1
0
-1
-1
0
1
q_x/π

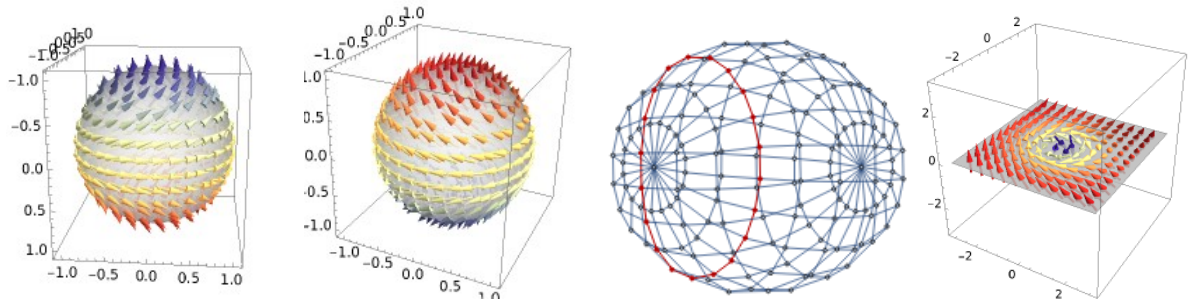

(d)
1
0
-1
q_y/π
-1
0
1
q_x/π

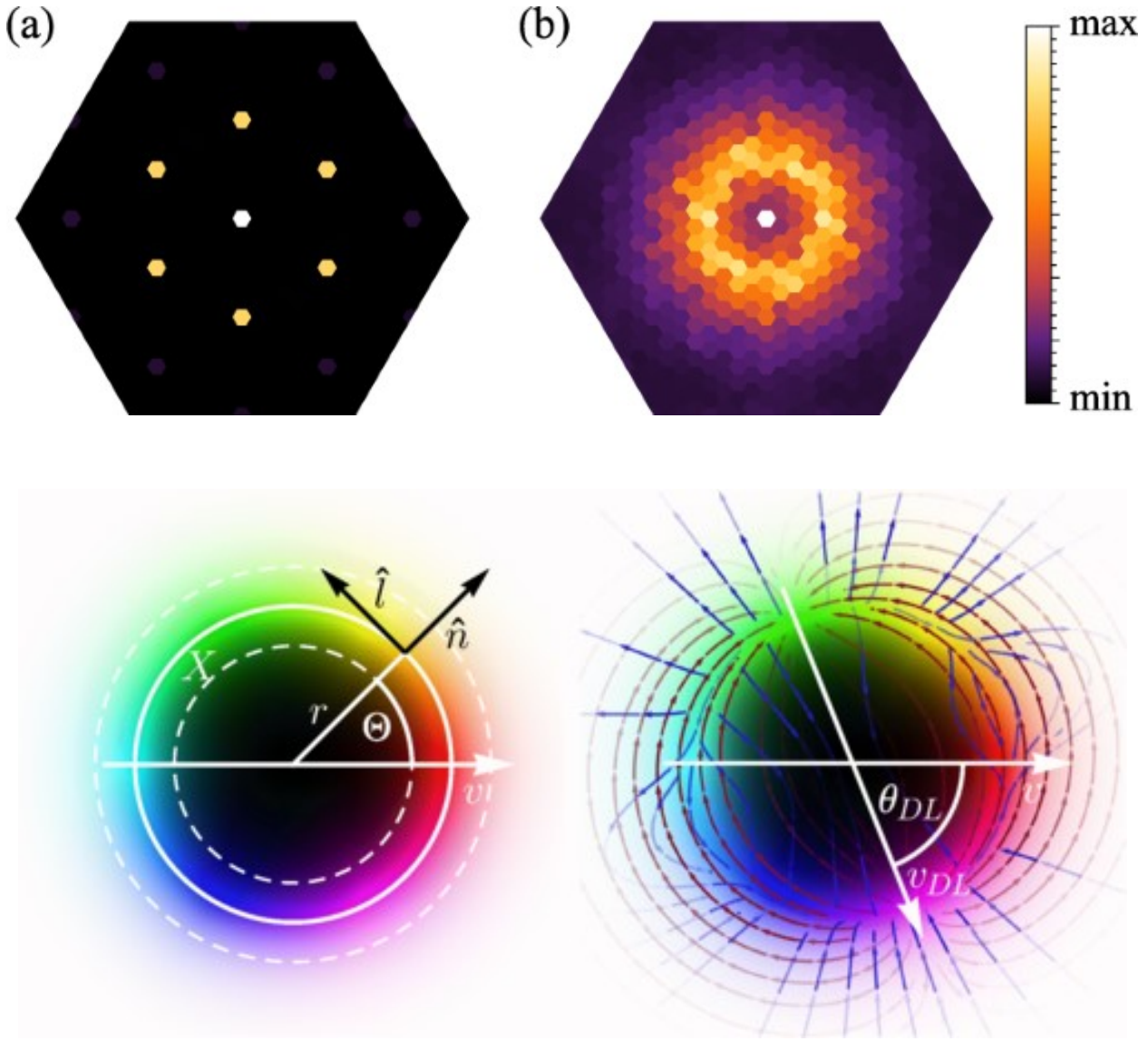

(e)
1
0
-1
-1
0
1
q_x/π

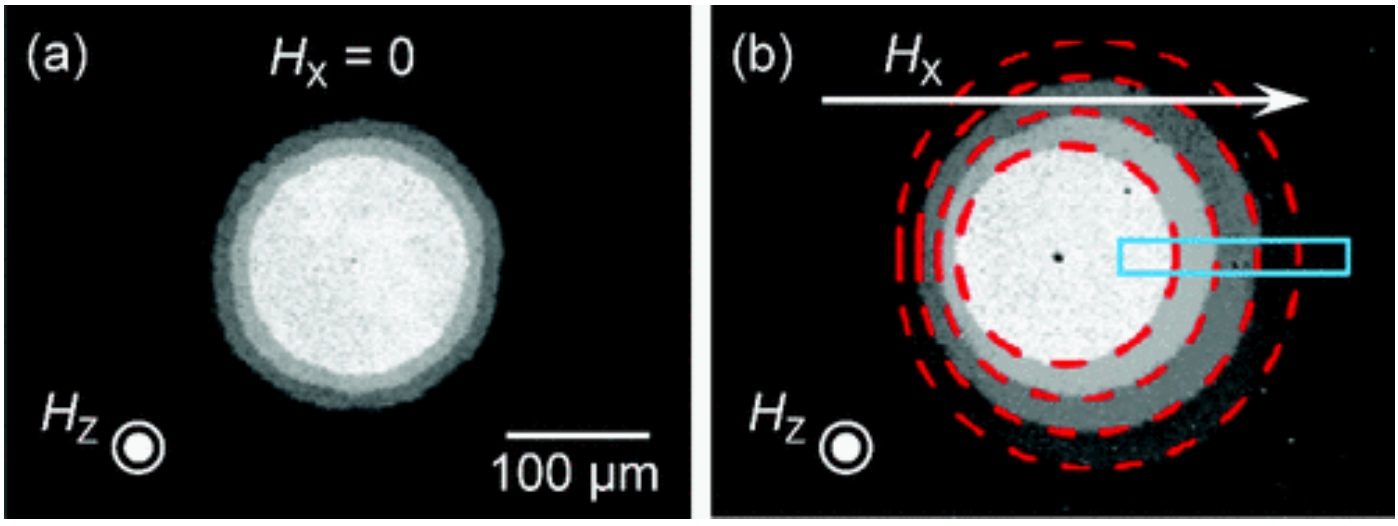

(a)
(b)
(c)
(d)
(e)
(f)
(g)
(h)
Q_1
Q_2
Q_3
Γ
X
M
q_x/π
q_y/π
ω/J
1×10^{-3}
5×10^{-5}
1×10^{-4}
5×10^{-6}
2×10^{-5}
5×10^{-4}
0.01
N_{ok}
$\langle M_z\rangle$
T/J
T = J
T = 2J
X
Y

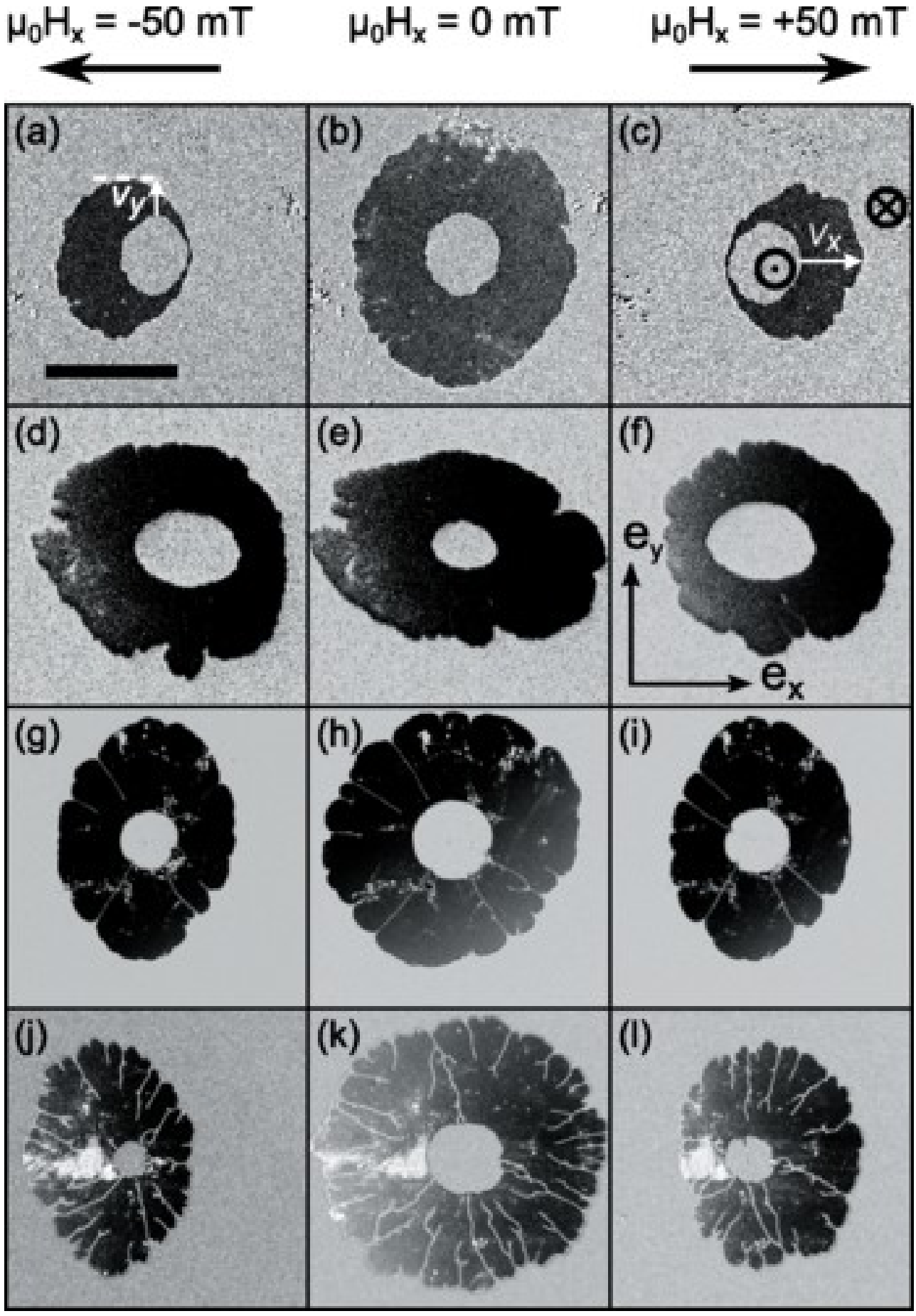

(a)
S_z
1
0
-1
Y
X
0
25
50
75
100


(b)
Y
X
0
25
50
75
100

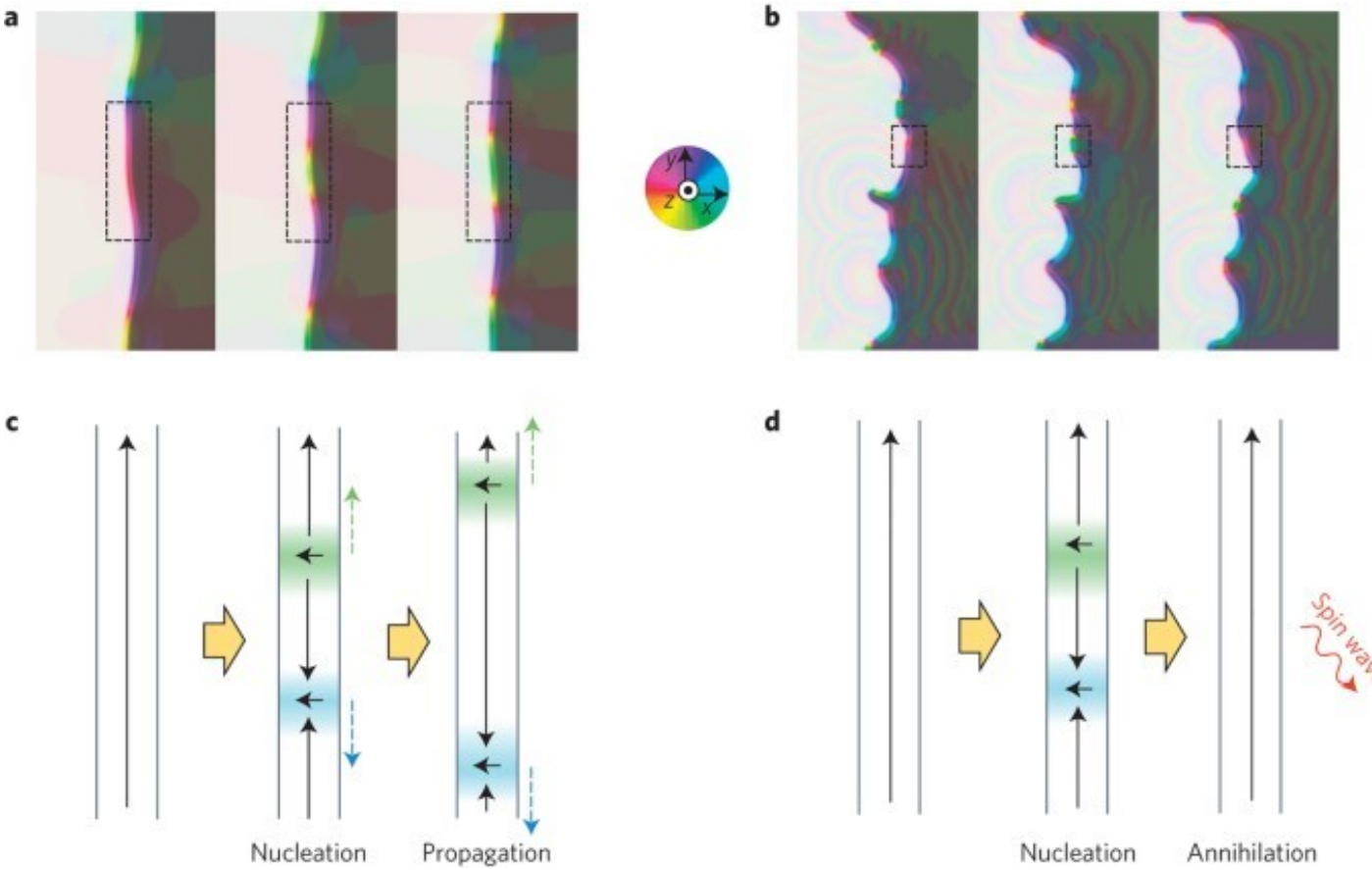


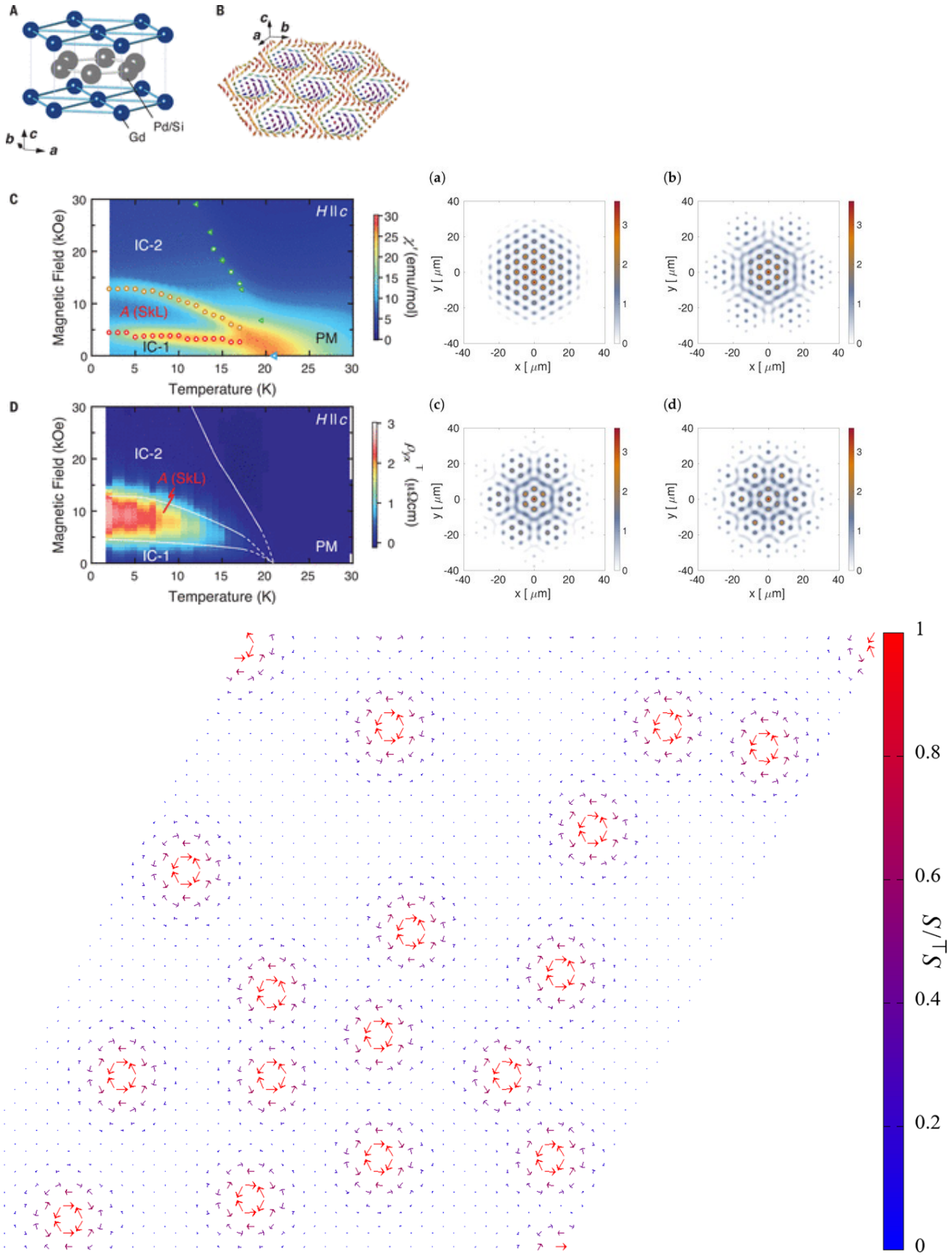

(a)
(b)
max
min
$\hat{l}$
$\hat{n}$
r
Θ
v_l
θ_{DL}
v
v_{DL}

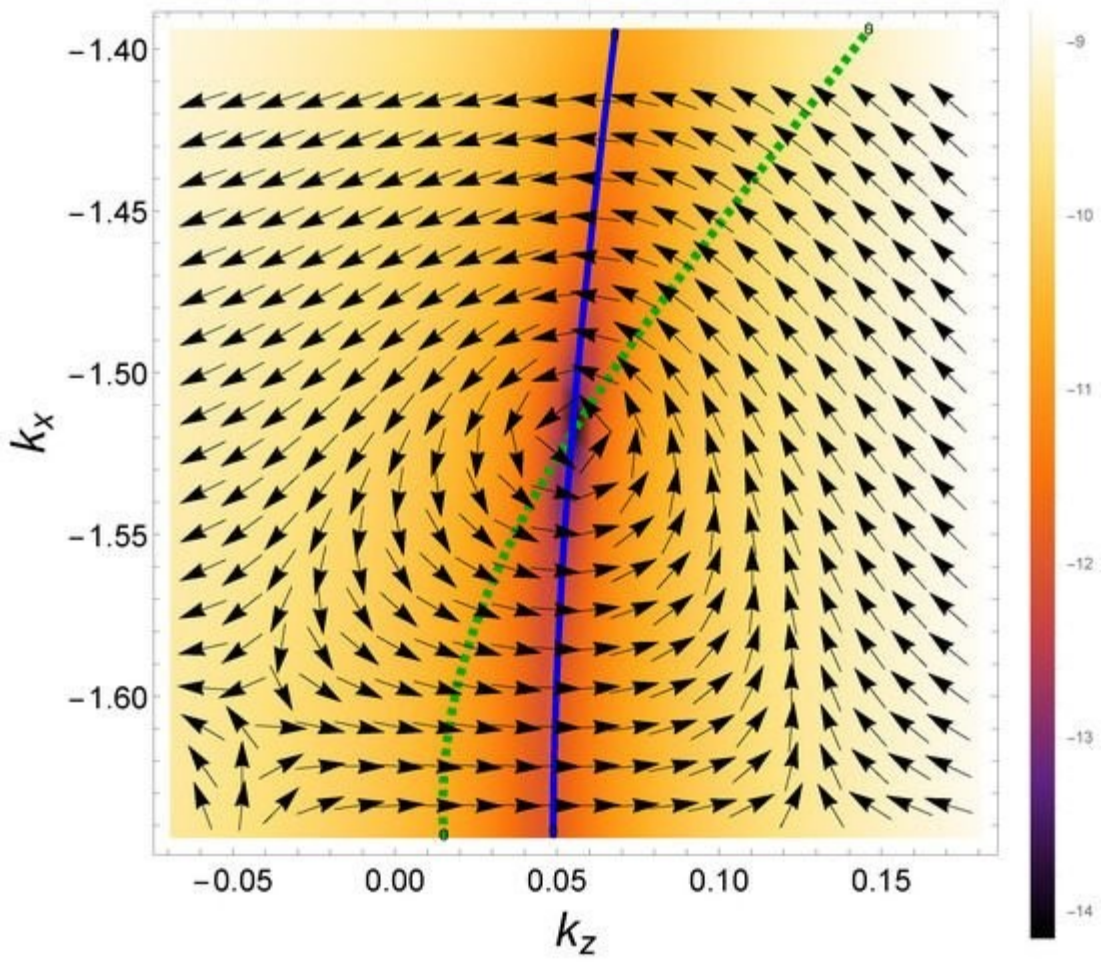

(a)
$H_x = 0$
H_z
100 μm
(b)
H_x
H_z

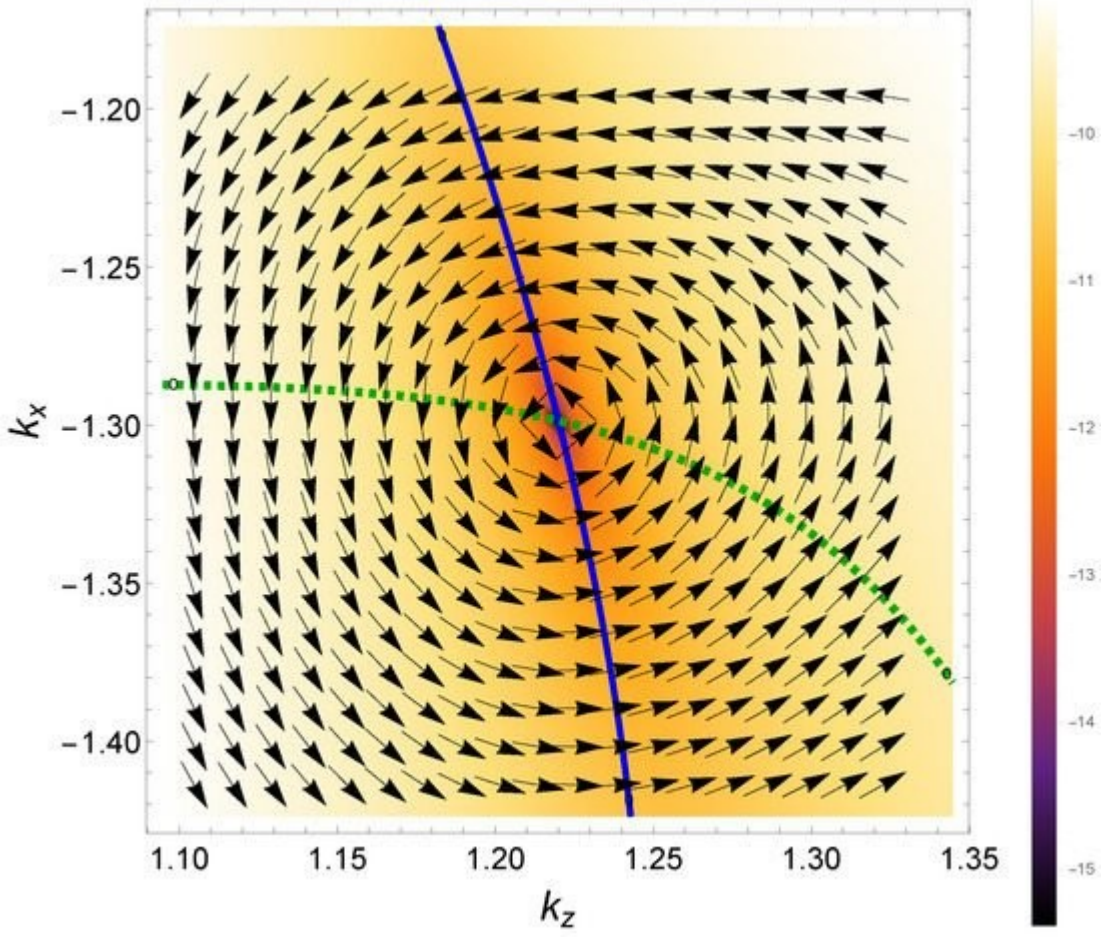

μ0Hx = -50 mT
μ0Hx = 0 mT
μ0Hx = +50 mT
(a)
(b)
(c)
(d)
(e)
(f)
(g)
(h)
(i)
(j)
(k)
(l)
vy
vx
ey
ex

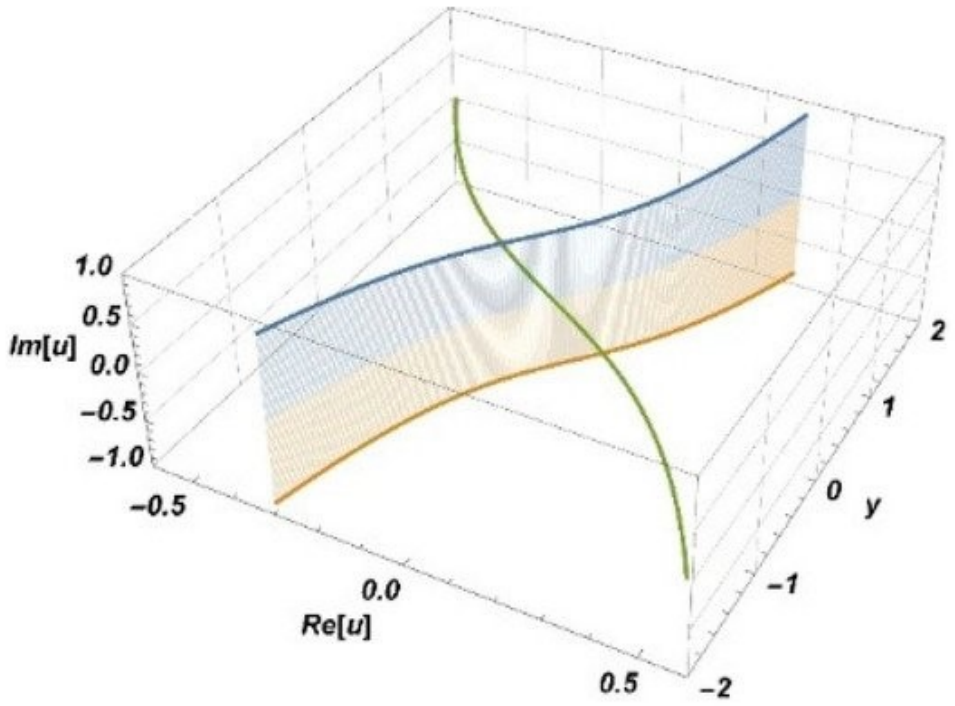
(a)
(b)
(c)

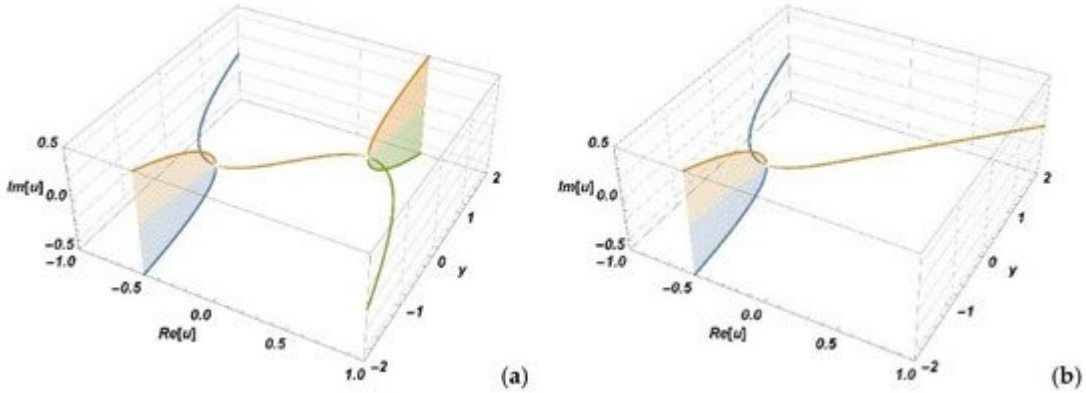

a
b
y
z
x
c
d
Nucleation
Propagation
Spin wave
Nucleation
Annihilation

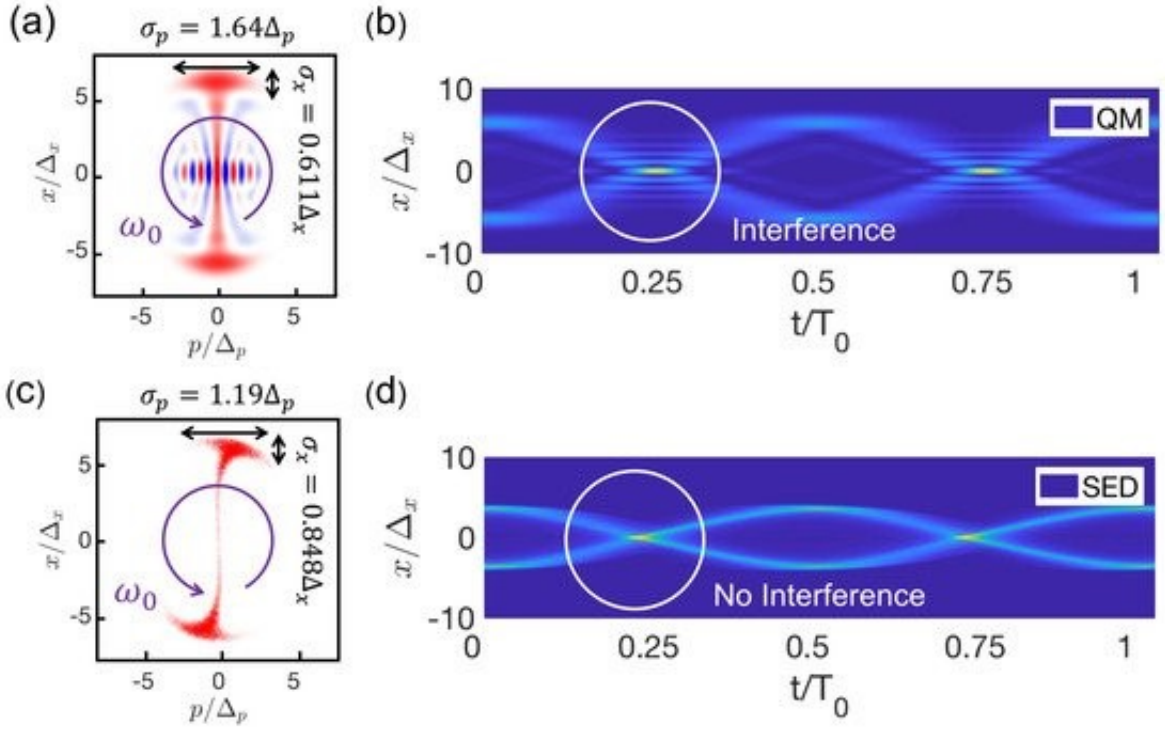

A
Gd
Pd/Si
B
C
Magnetic Field (kOe)
Temperature (K)
H ∥ c
IC-2
A (SkL)
IC-1
PM
χ′ (emu/mol)
D
ρ_yx (μΩcm)
(a)
(b)
(c)
(d)
y [μm]
x [μm]
S/|S|

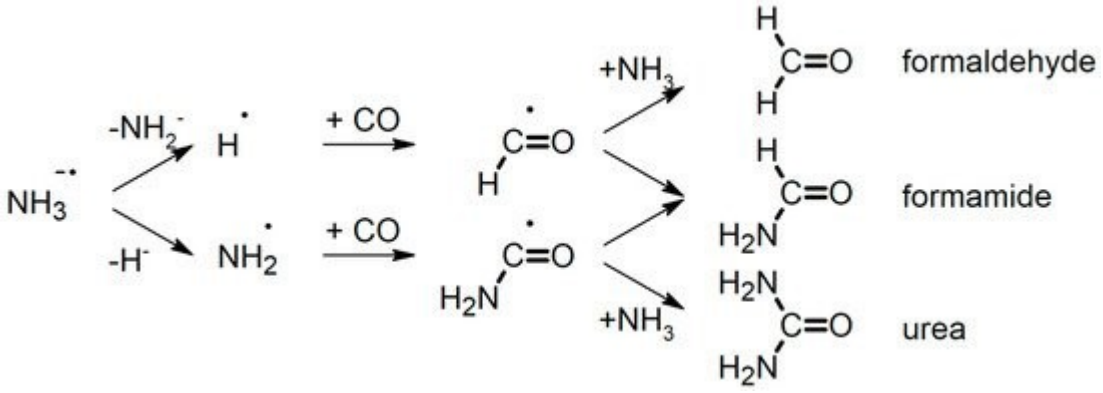

−1.40
−1.45
−1.50
−1.55
−1.60
k_x
−0.05
0.00
0.05
0.10
0.15
k_z
−9
−10
−11
−12
−13
−14

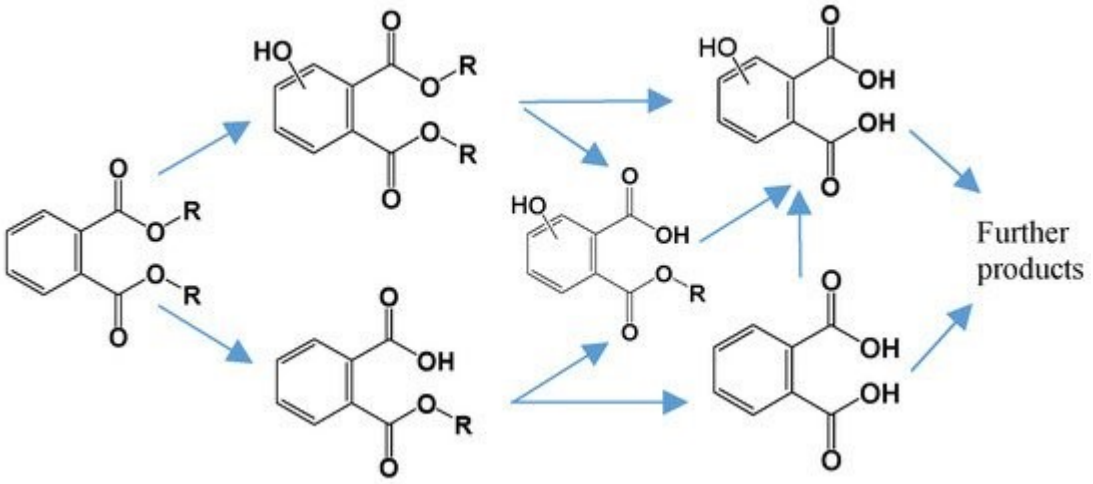

−1.20
−1.25
−1.30
−1.35
−1.40
k_x
1.10
1.15
1.20
1.25
1.30
1.35
k_z
−10
−11
−12
−13
−14
−15

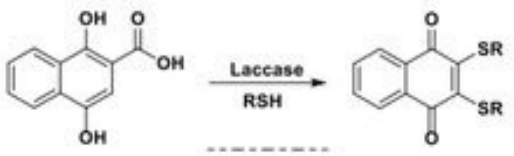

Im[u]
1.0
0.5
0.0
−0.5
−1.0
−0.5
0.0
0.5
Re[u]
2
1
0
−1
−2
y

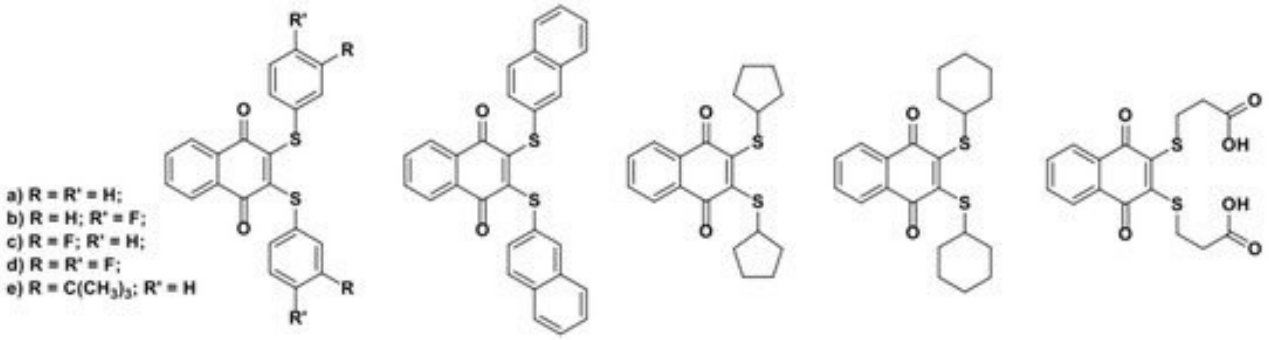

(a)
(b)

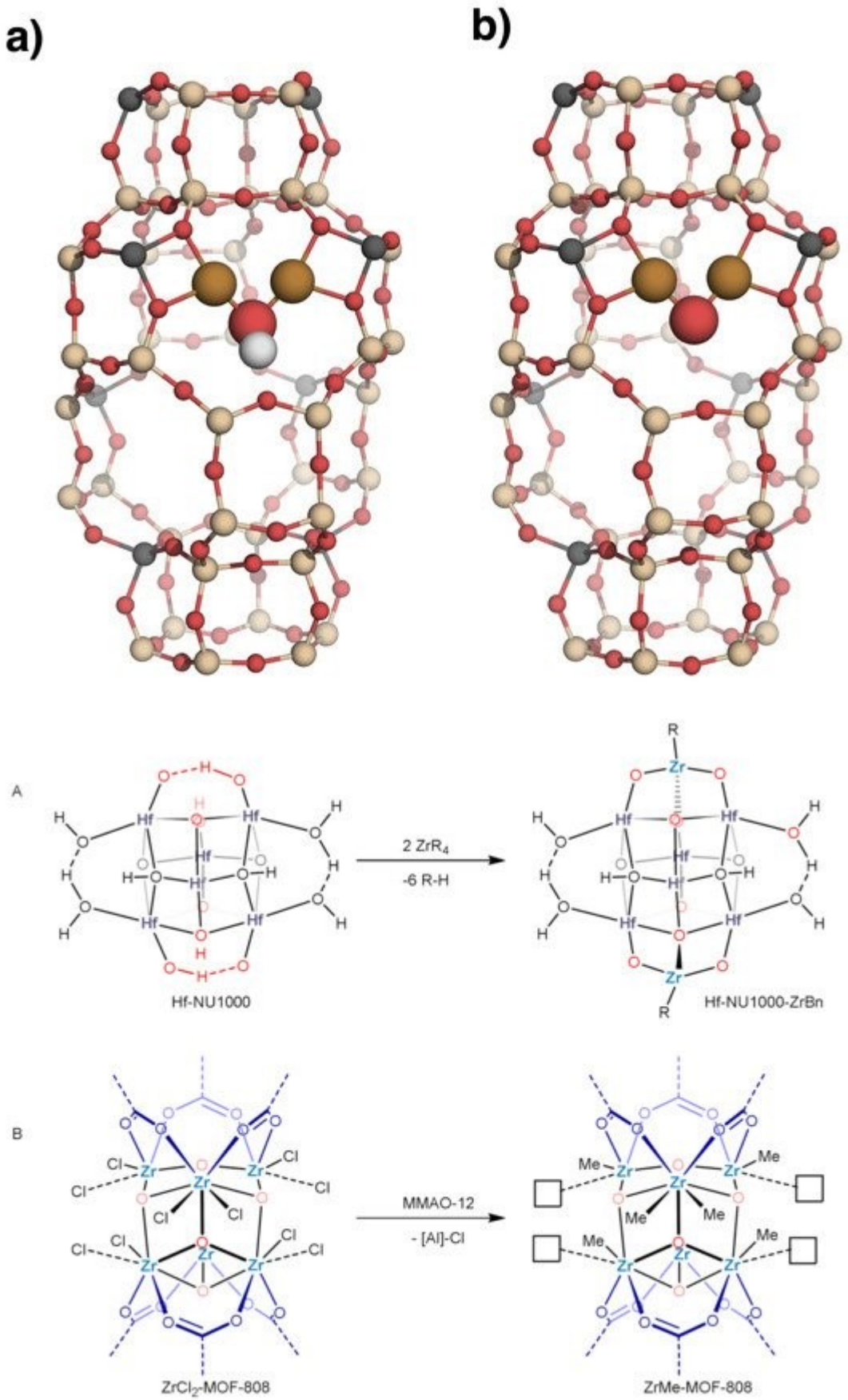

(a)
$\sigma_p = 1.64\Delta_p$
$\sigma_x = 0.611\Delta_x$
ω_0
x/Δ_x
p/Δ_p
(b)
QM
Interference
t/T_0
(c)
$\sigma_p = 1.19\Delta_p$
$\sigma_x = 0.848\Delta_x$
(d)
SED
No Interference


NH3
-NH2
-H
H
NH2
+ CO
+ CO
C=O
H
H2N
+NH3
+NH3
formaldehyde
formamide
urea

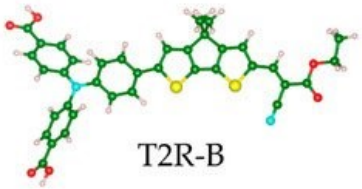

HO
O
R
OH
Further
products


OH
O
Laccase
RSH
SR


a) R = R' = H;
b) R = H; R' = F;
c) R = F; R' = H;
d) R = R' = F;
e) R = C(CH3)3; R' = H
R'
R
S
O
OH

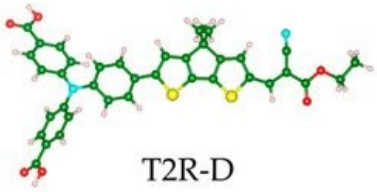

a)
b)
A
Hf-NU1000
2 ZrR4
-6 R-H
Hf-NU1000-ZrBn
B
ZrCl2-MOF-808
MMAO-12
- [Al]-Cl
ZrMe-MOF-808

T2R-A

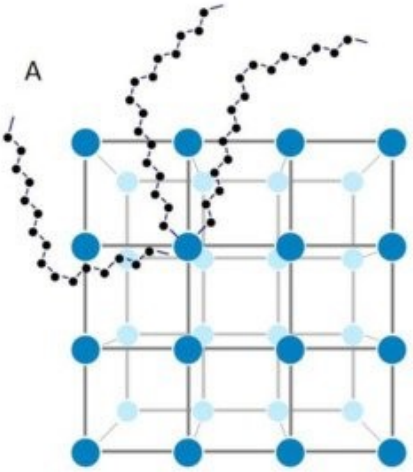


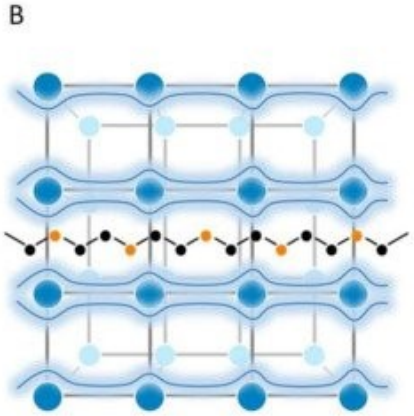
T2R-B

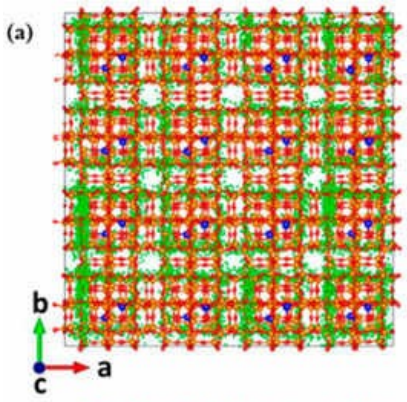
T2R-C

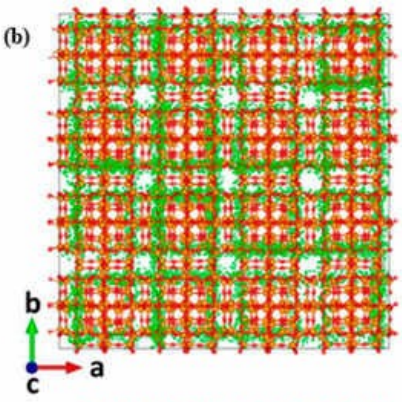


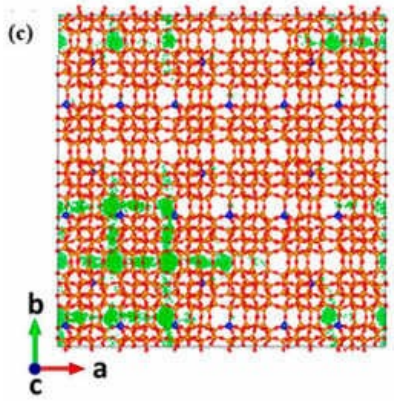
T2R-D

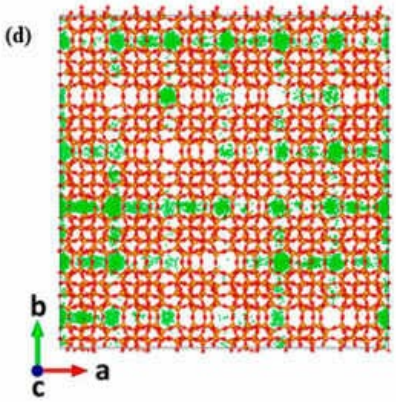


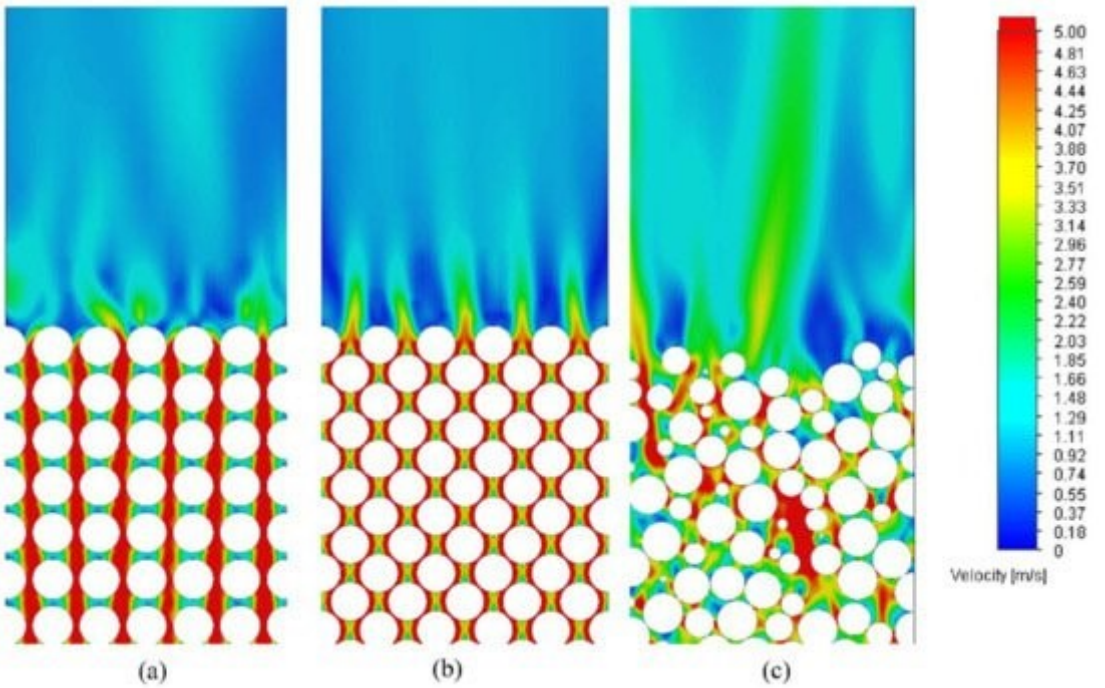


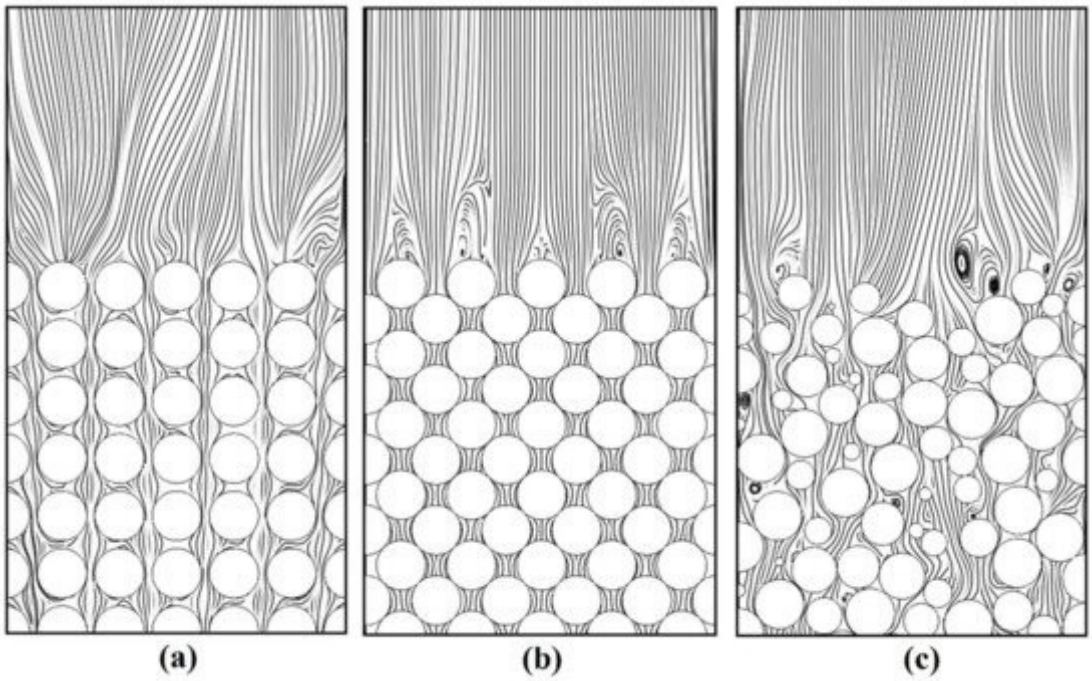


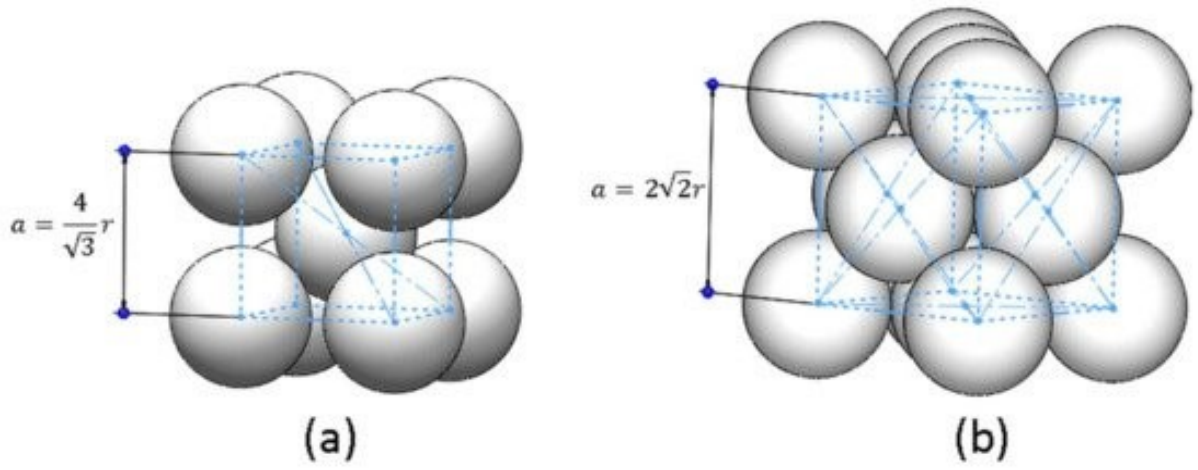


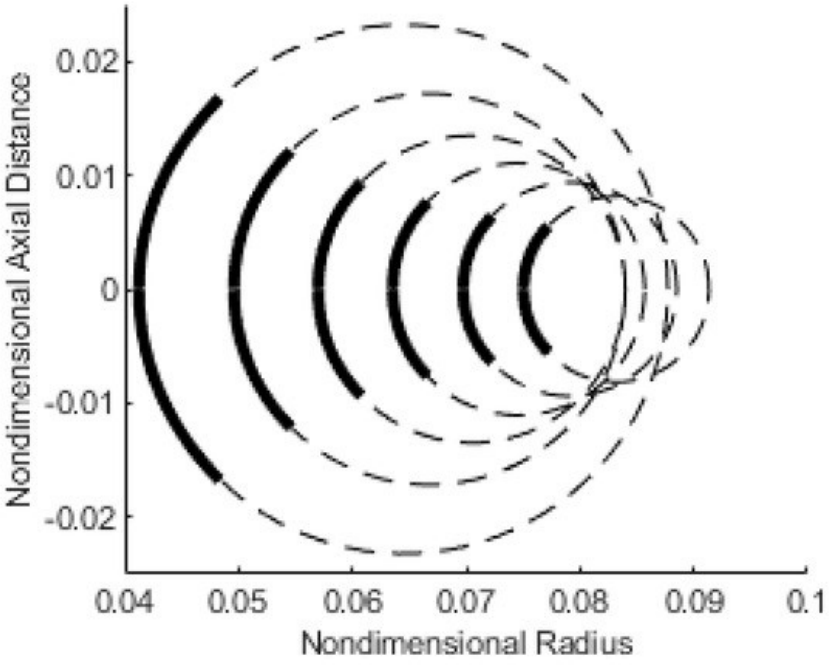


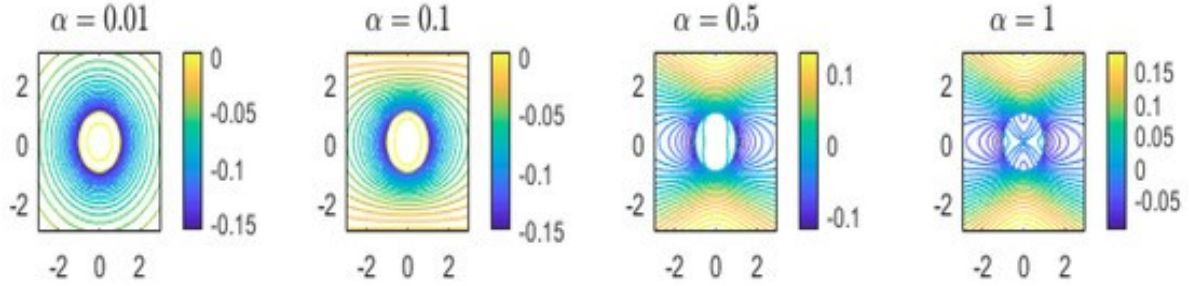


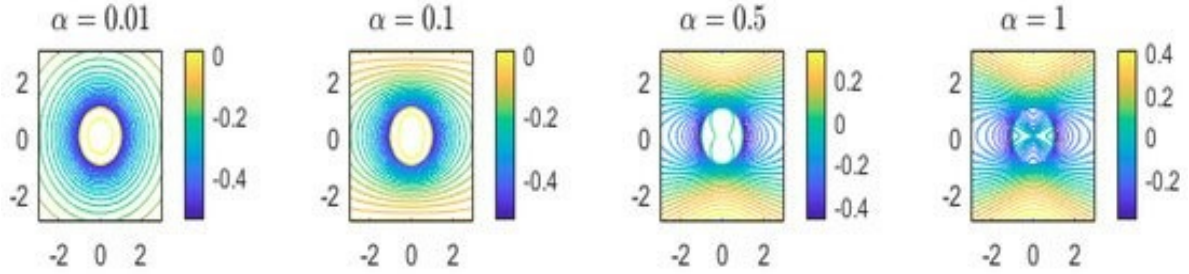

5.00
4.81
4.63
4.44
4.25
4.07
3.88
3.70
3.51
3.33
3.14
2.96
2.77
2.59
2.40
2.22
2.03
1.85
1.66
1.48
1.29
1.11
0.92
0.74
0.55
0.37
0.18
0
Velocity [m/s]
(a)
(b)
(c)

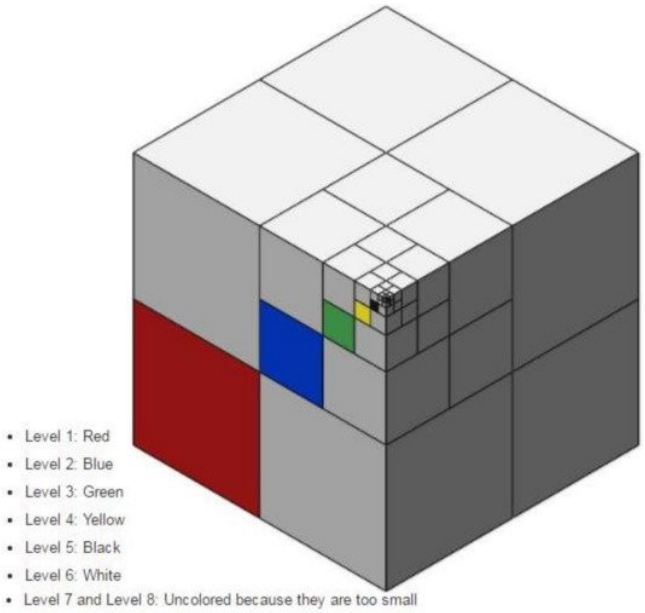

(a)
(b)
(c)


$a = \frac{4}{\sqrt{3}}r$
$a = 2\sqrt{2}r$
(a)
(b)

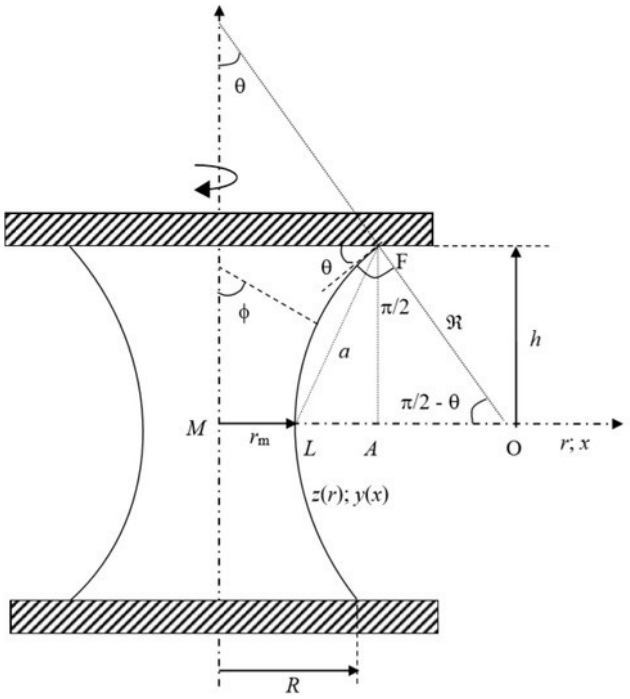


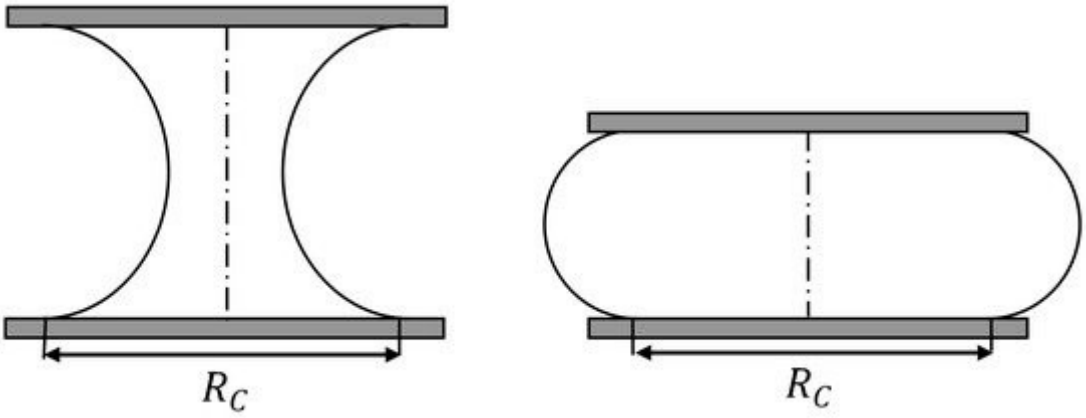


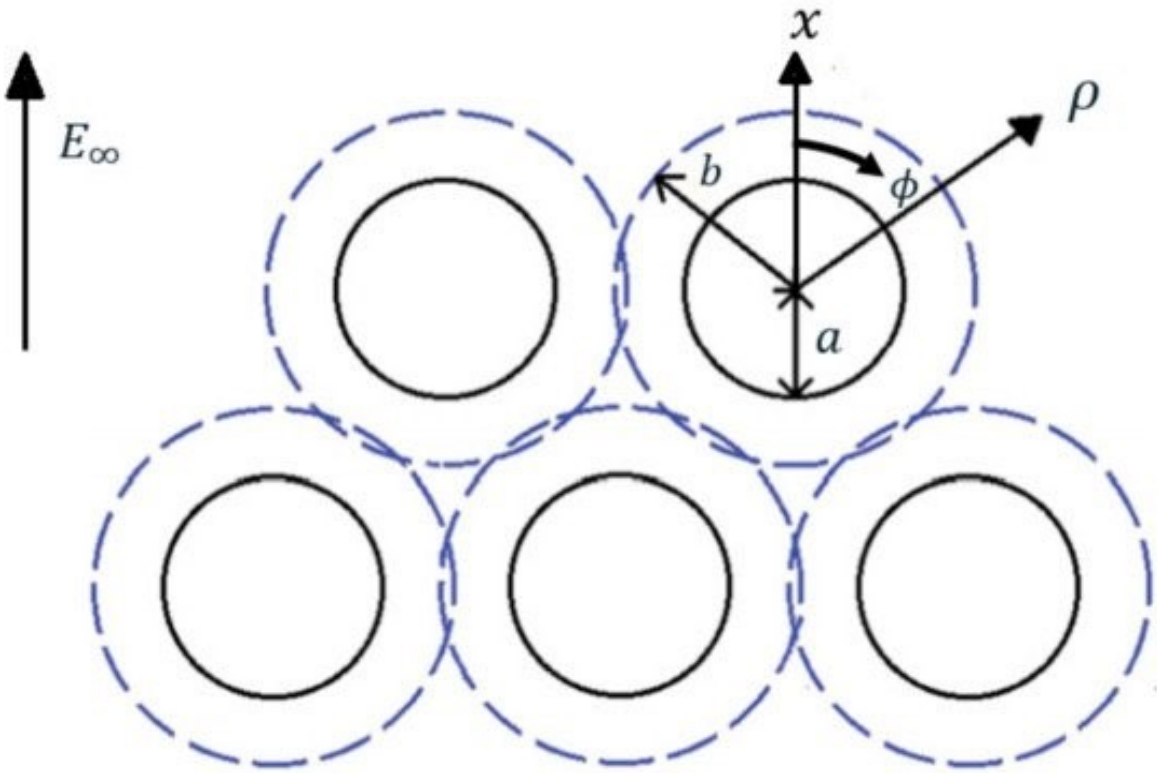


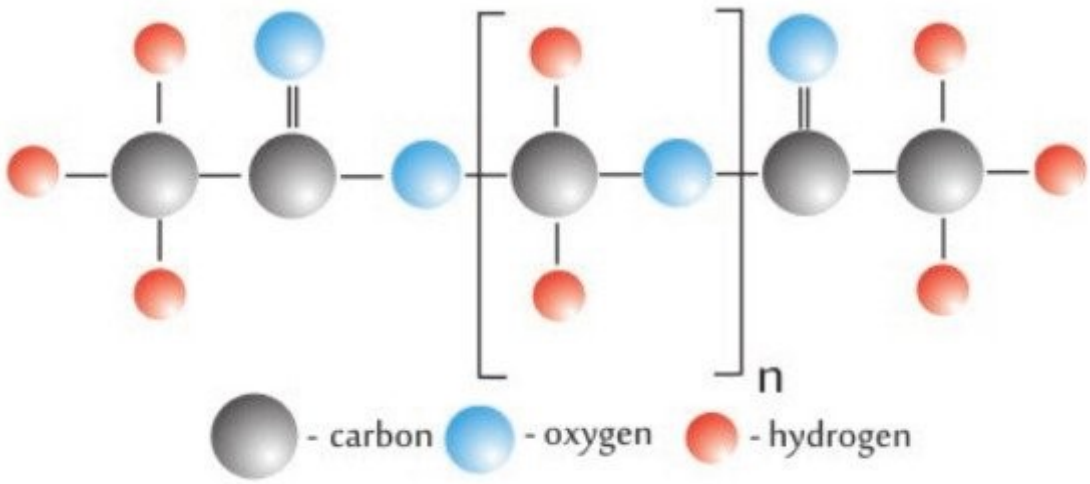


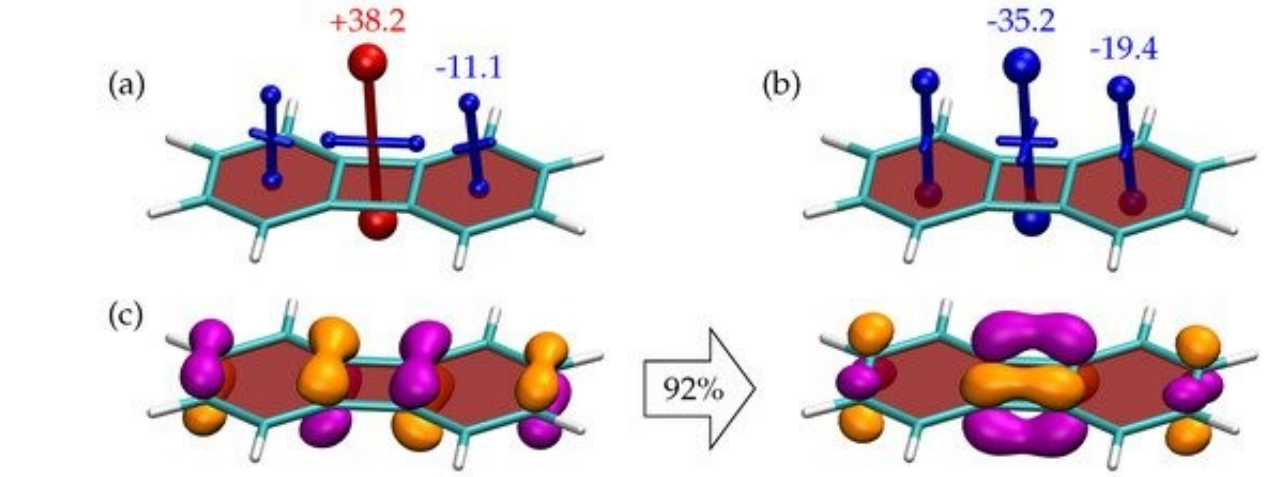
- Level 1: Red
- Level 2: Blue
- Level 3: Green
- Level 4: Yellow
- Level 5: Black
- Level 6: White
- Level 7 and Level 8: Uncolored because they are too small

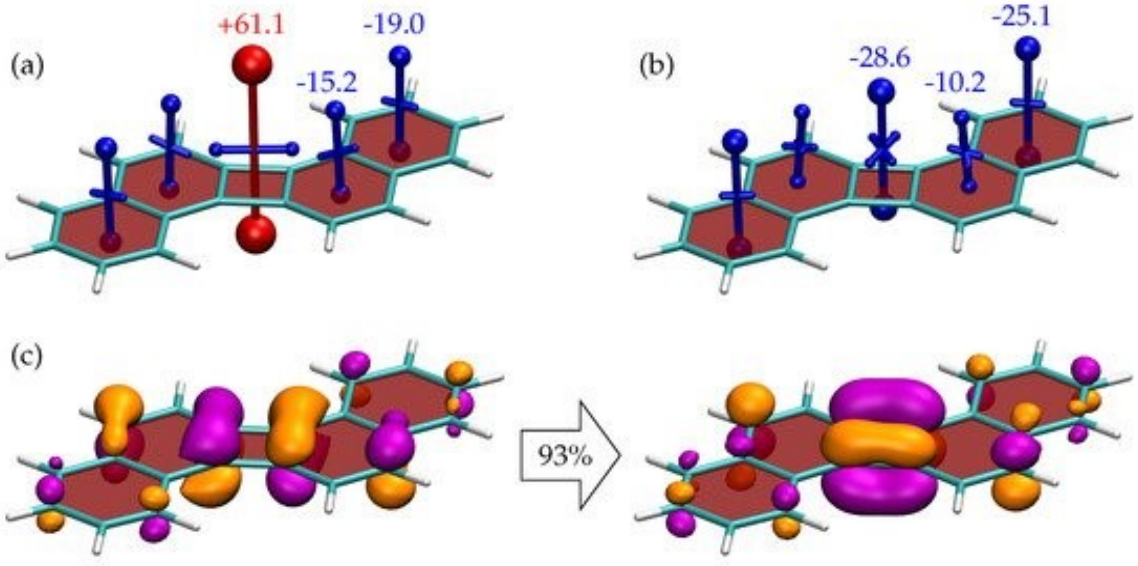

θ
θ
F
ϕ
π/2
ℜ
h
a
π/2 - θ
M
r_m
L
A
O
r; x
z(r); y(x)
R

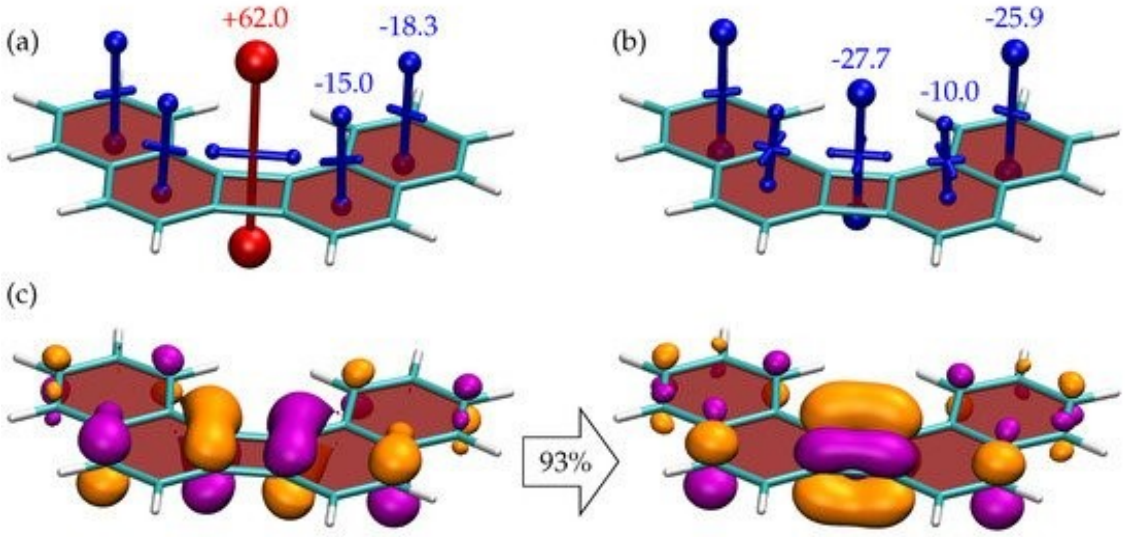

R_C
R_C

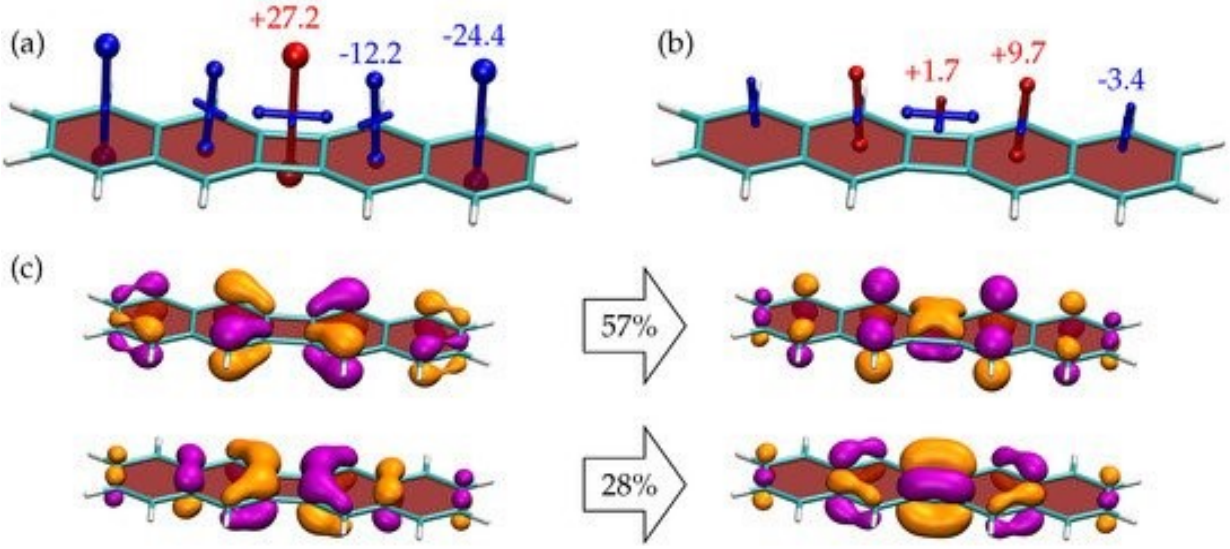

E_∞
x
ρ
b
ϕ
a

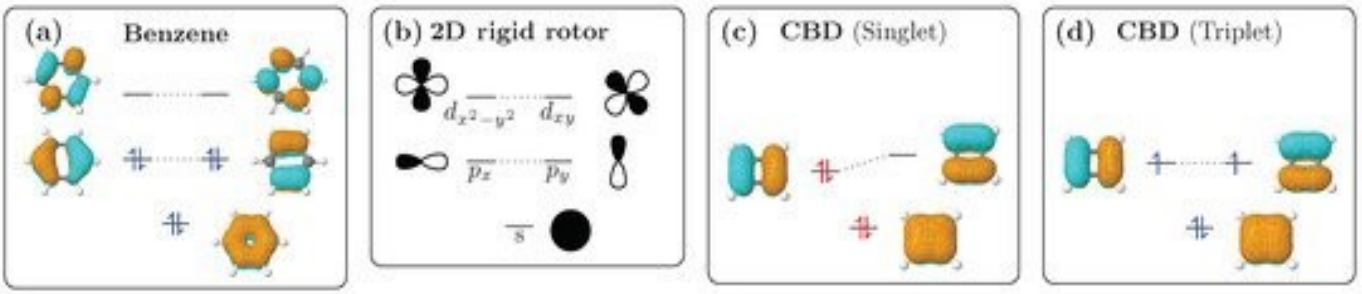

n
- carbon
- oxygen
- hydrogen


(a)
+38.2
-11.1
(b)
-35.2
-19.4
(c)
92%

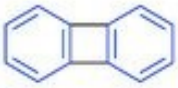

(a)
+61.1
-19.0
-15.2
(b)
-25.1
-28.6
-10.2
(c)
93%


(a)
+62.0
-18.3
-15.0
(b)
-25.9
-27.7
-10.0
(c)
93%

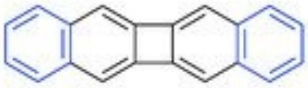

(a)
+27.2
-12.2
-24.4
(b)
+1.7
+9.7
-3.4
(c)
57%
28%


(a) Benzene
(b) 2D rigid rotor
(c) CBD (Singlet)
(d) CBD (Triplet)

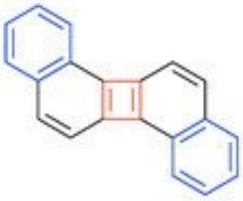
Cyclobutadiene (**1**)



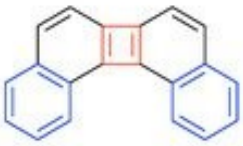
Biphenylene (**2**)



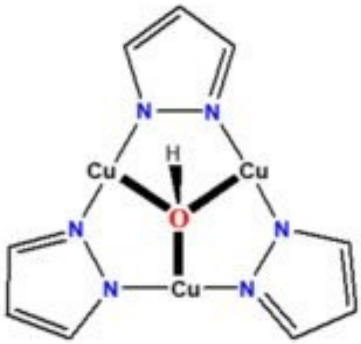
Dibenzo[b,h]biphenylene (**3**)



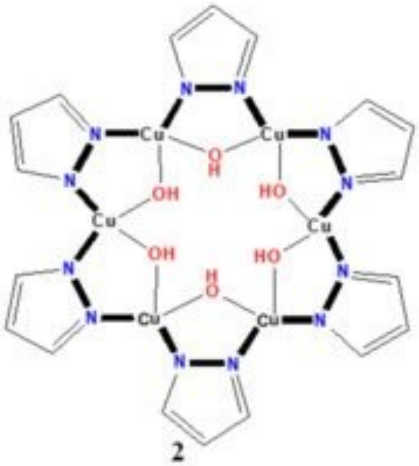
Dibenzo[a,g]biphenylene (**4**)



Dibenzo[a,i]biphenylene (**5**)

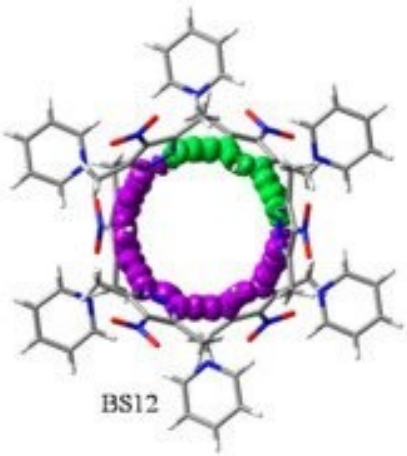


1

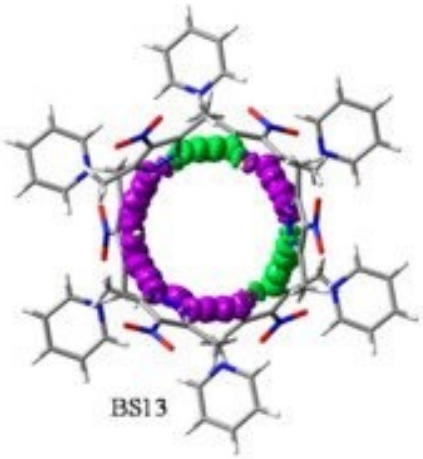


2

3

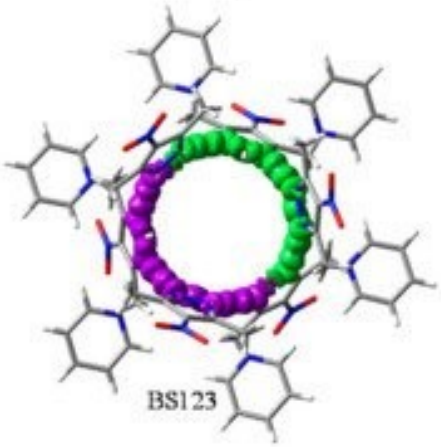


BS12



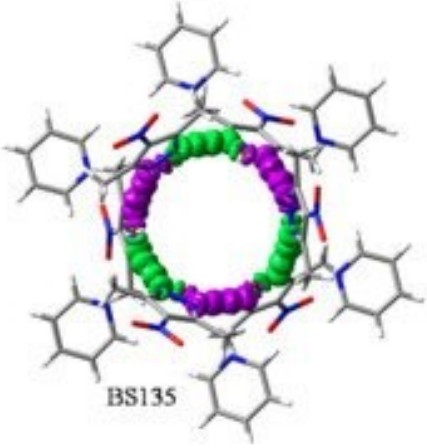
BS13

BS14

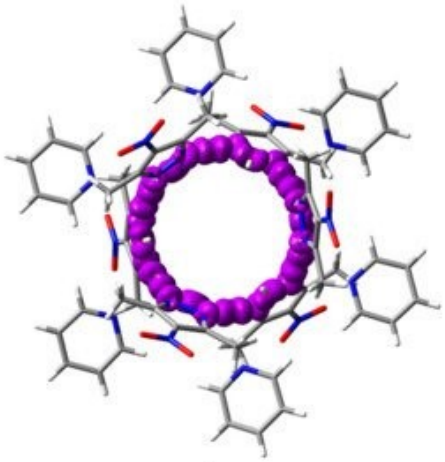


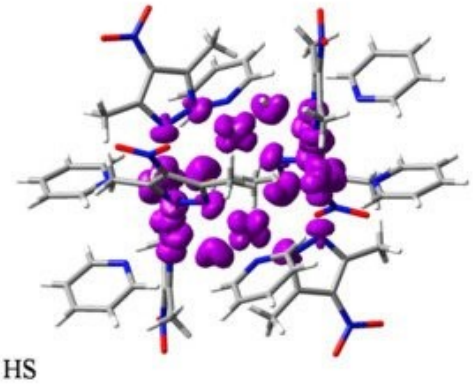
BS123

BS124

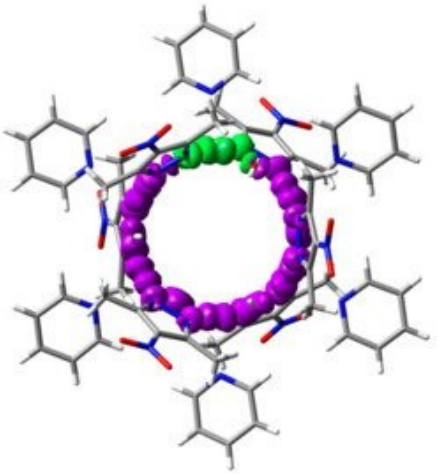


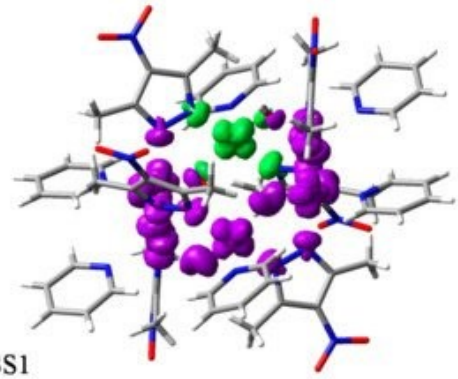
BS135



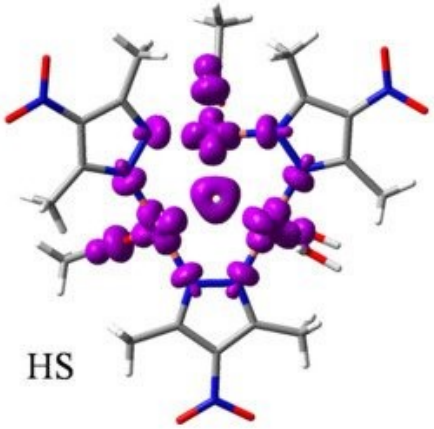


HS

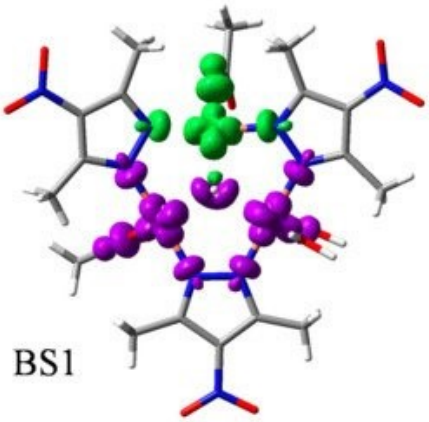




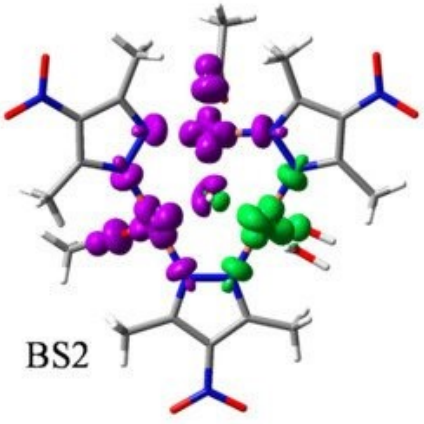
BS1



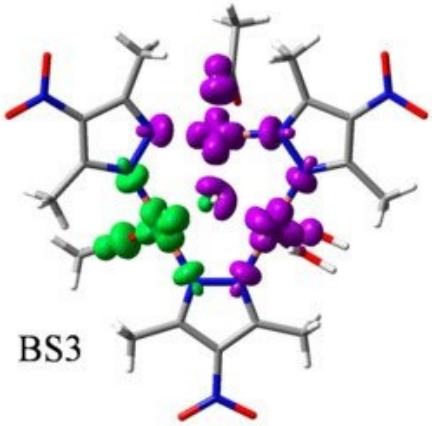
HS



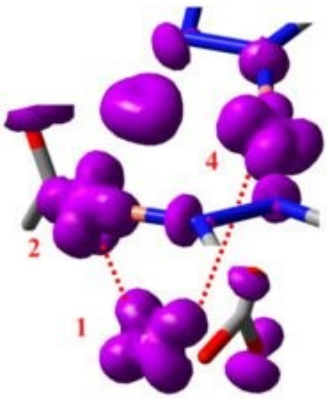
BS1



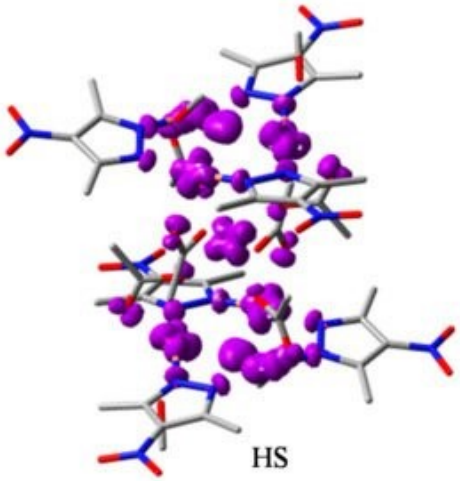
BS2



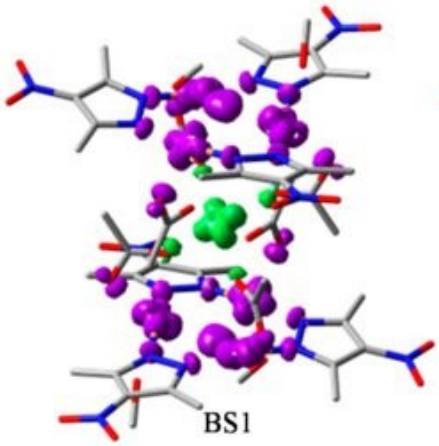
BS3



Spin density on selected magnetic orbitals (close-up)

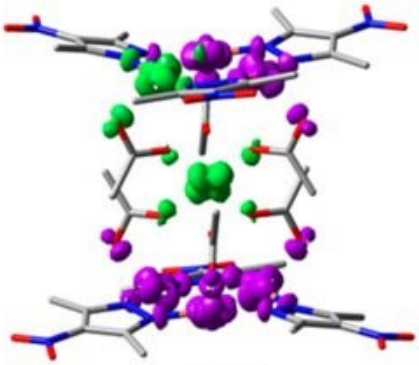


HS

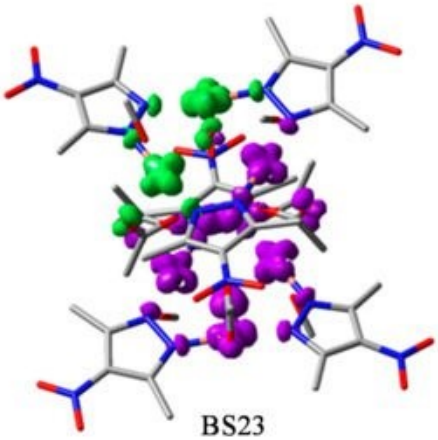


BS1

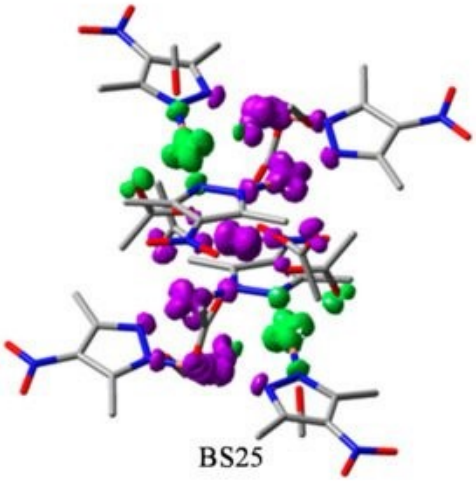
BS2



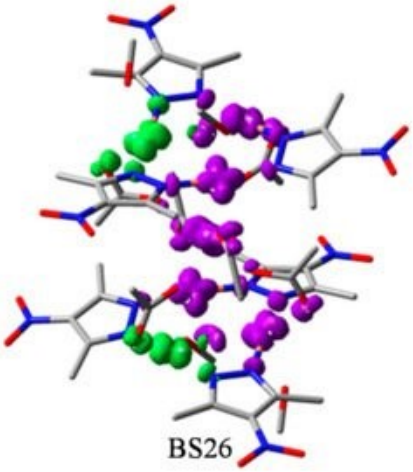
BS12



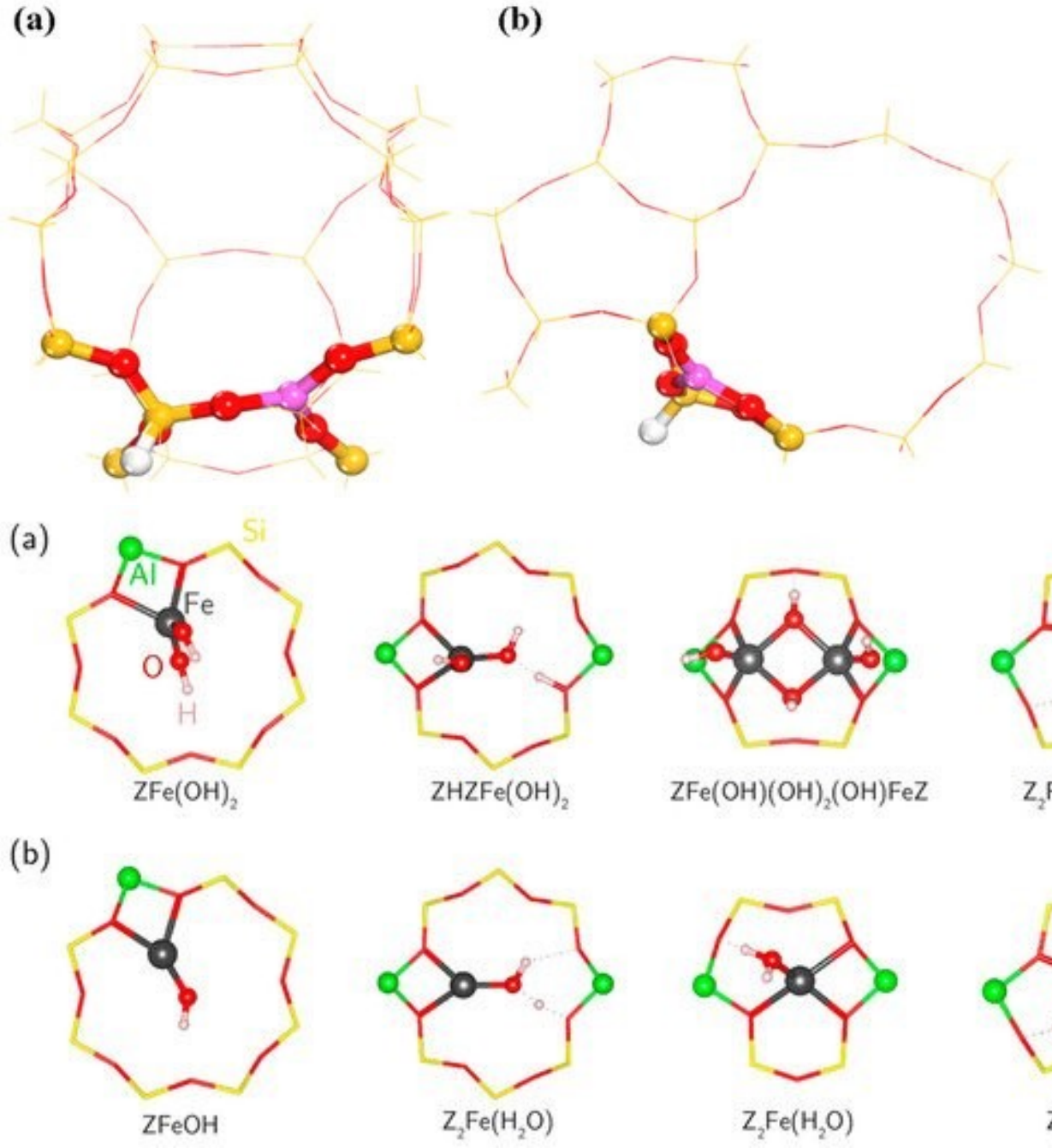
BS23

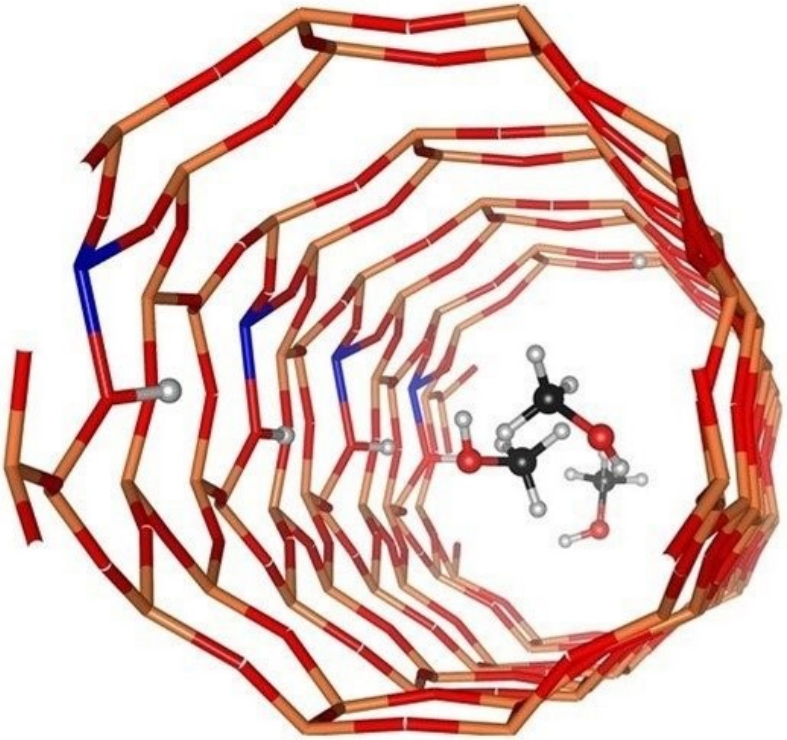


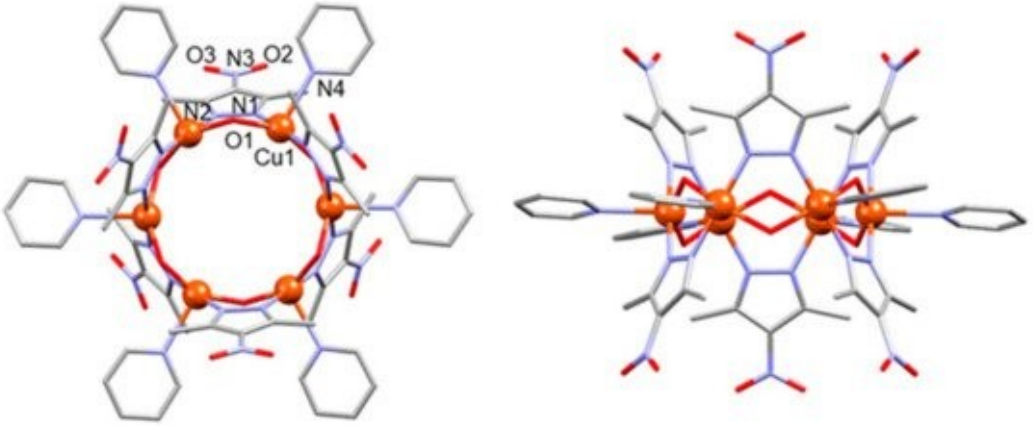
BS25

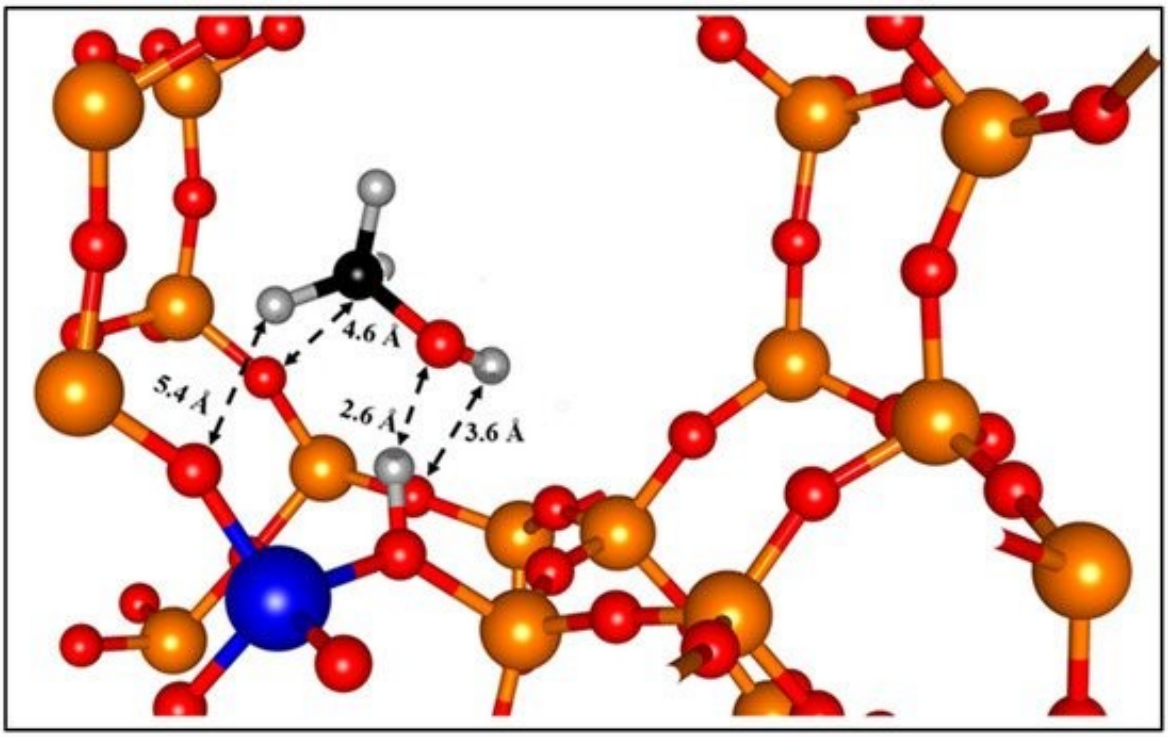


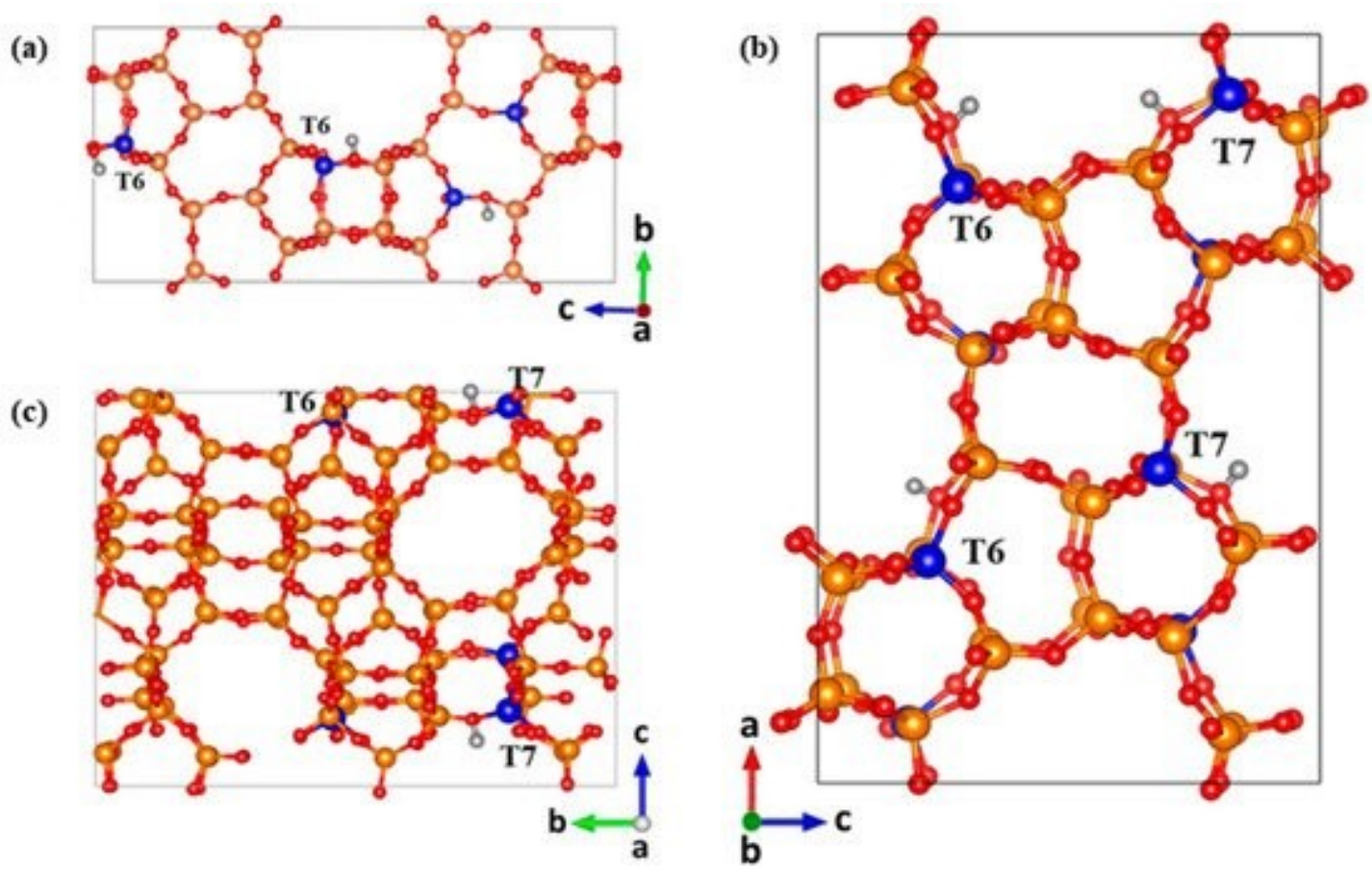
BS26

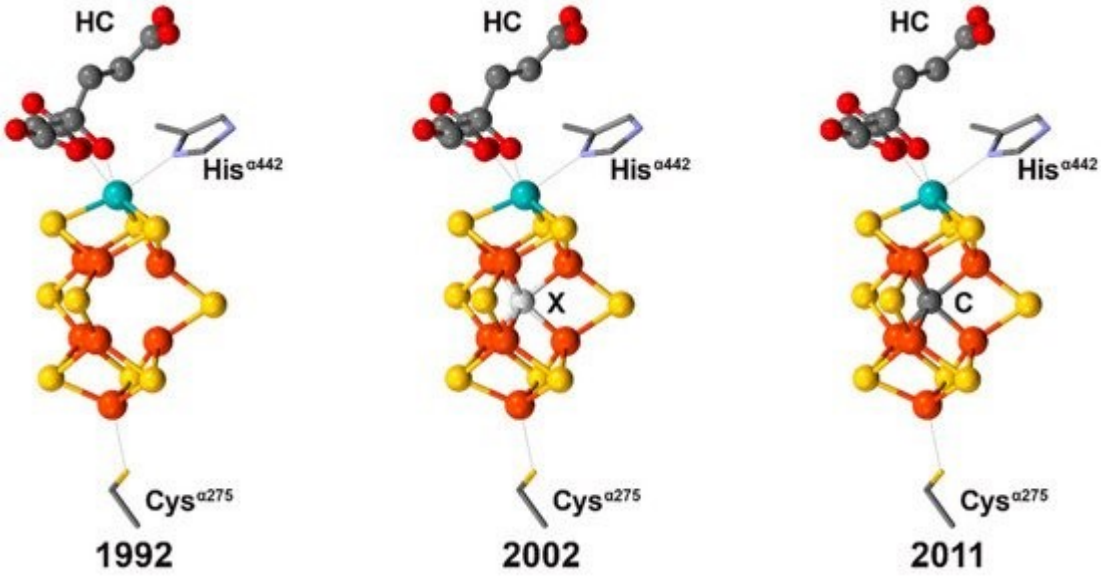

(a)
(b)
(a)
Si
Al
Fe
O
H
ZFe(OH)2
ZHZFe(OH)2
ZFe(OH)(OH)2(OH)FeZ
Z2FeOH(H2O)
(b)
ZFeOH
Z2Fe(H2O)
Z2Fe(H2O)
Z2Fe(H2O)

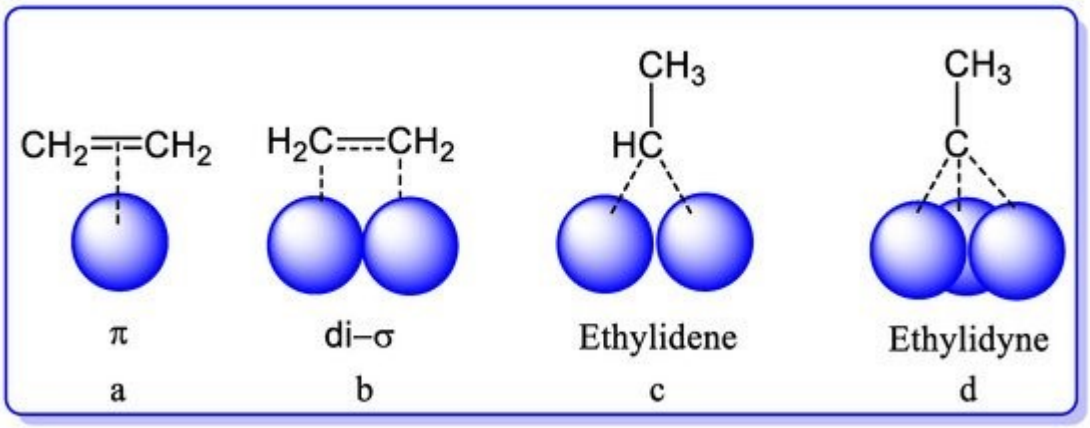


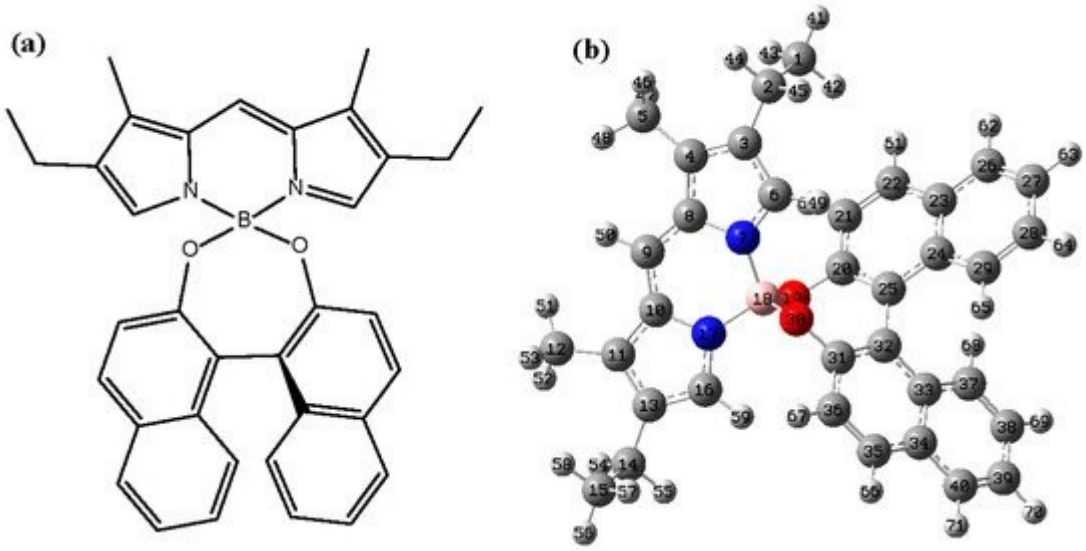

O3
N3
O2
N4
N2
N1
O1
Cu1

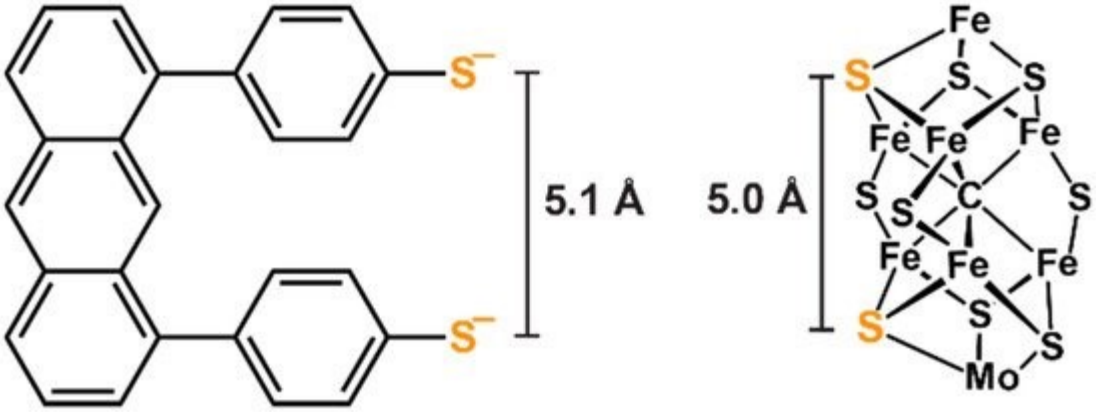

4.6 Å
5.4 Å
2.6 Å
3.6 Å

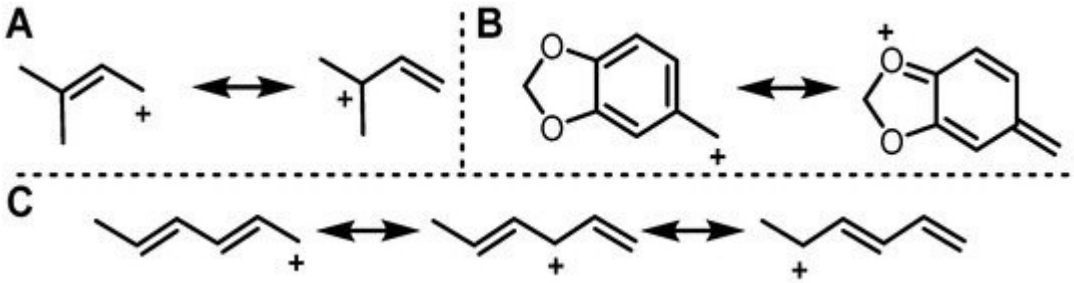

(a)
T6
T6
b
c
a
(b)
T7
T6
T7
T6
a
c
b
(c)
T6
T7
T7
c
b
a

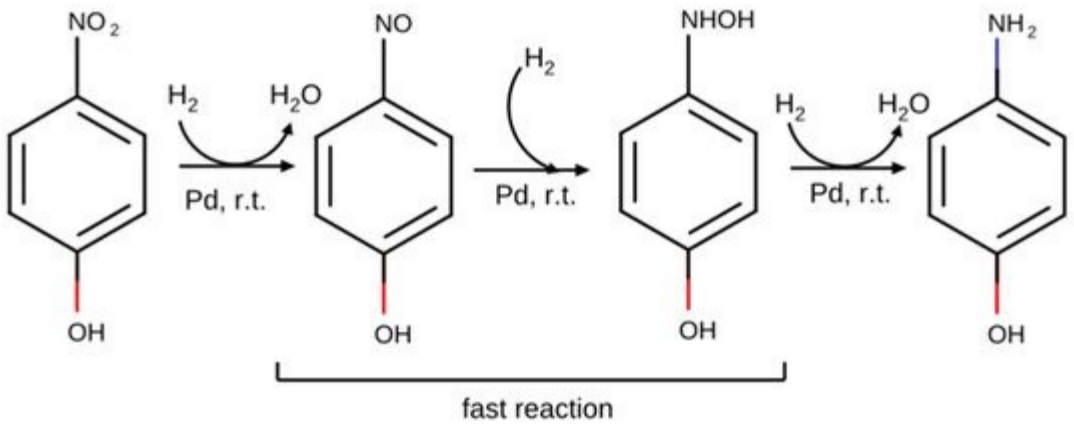

HC
His$^{\alpha 442}$
Cys$^{\alpha 275}$
1992
HC
His$^{\alpha 442}$
X
Cys$^{\alpha 275}$
2002
HC
His$^{\alpha 442}$
C
Cys$^{\alpha 275}$
2011


$CH_2{=}CH_2$
π
a
$H_2C{=}CH_2$
di–σ
b
CH_3
HC
Ethylidene
c
CH_3
C
Ethylidyne
d

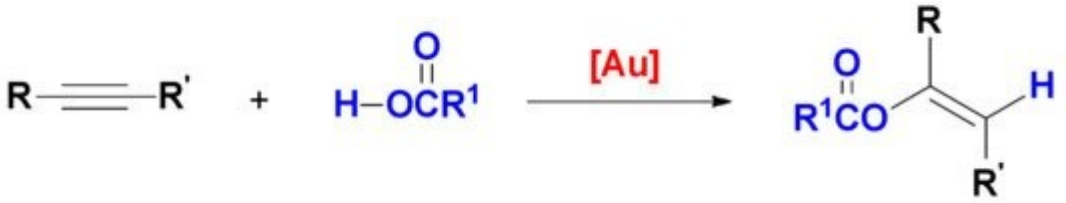

(a)
(b)

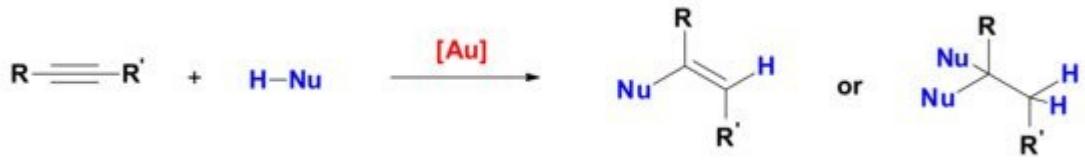

S⁻
S⁻
5.1 Å
5.0 Å
Fe
S
Mo
C

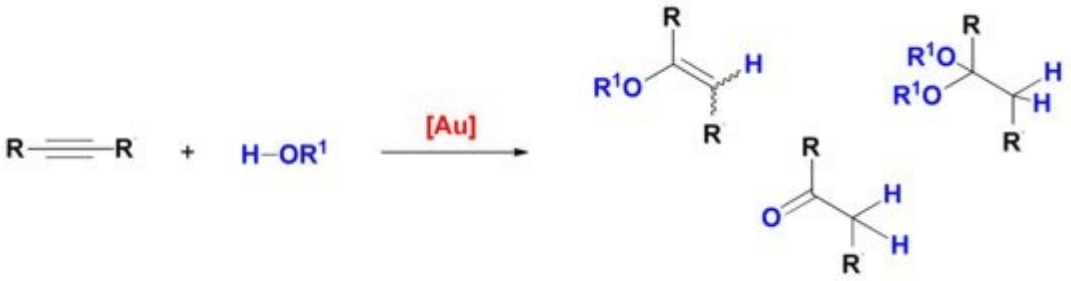

A
B
C

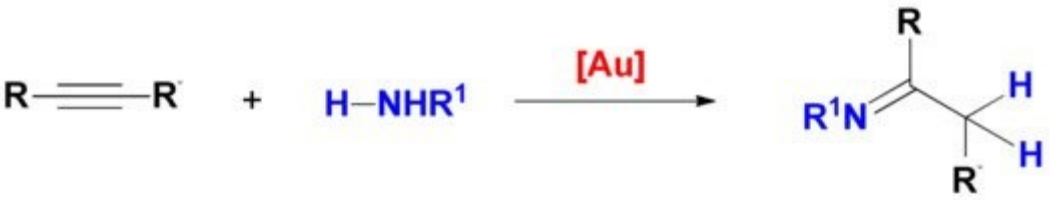

NO2
NO
NHOH
NH2
OH
H2
H2O
Pd, r.t.
fast reaction

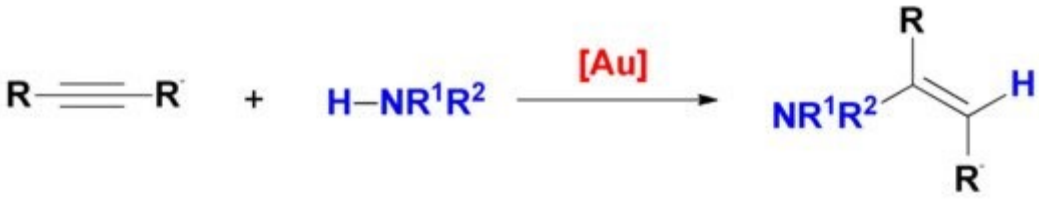
R
R'
+
H–OH
[Au]
O
H
H
R'


R
R'
+
O
H–OCR1
[Au]
O
R1CO
R
H
R'

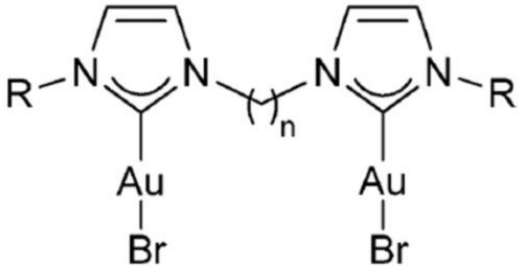

R
R'
+
H–Nu
[Au]
R
Nu
H
R'
or
R
Nu
Nu
H
H
R'

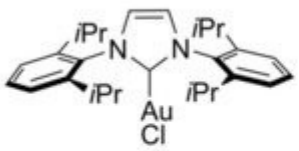

R
R
+
H–OR1
[Au]
R
R1O
H
R
R
R1O
R1O
H
H
R
R
O
H
H
R


R
R
+
H–NHR1
[Au]
R
R1N
H
H
R

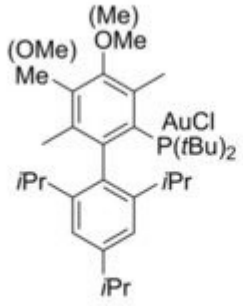

R
R
+
H–NR1R2
[Au]
R
NR1R2
H
R

';/7


R
N
N
n
N
N
R
Au
Br
Au
Br



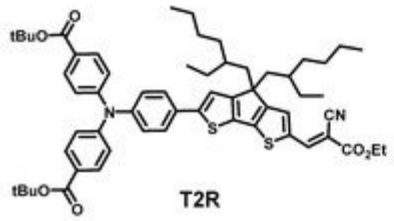
1



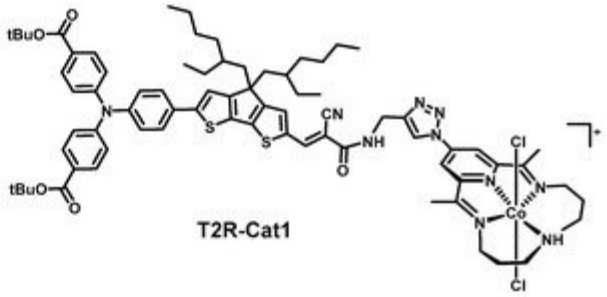
2

6

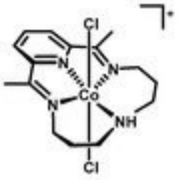
3



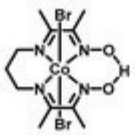
T2R



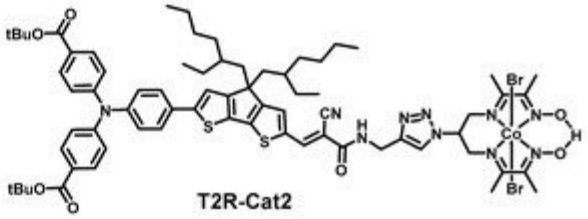
T2R-Cat1



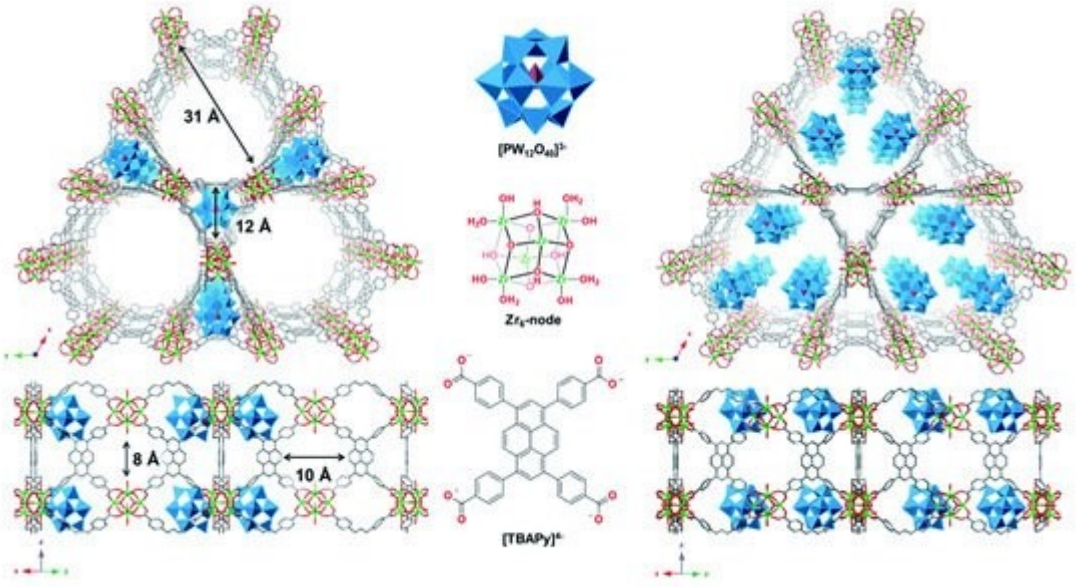
Cat1

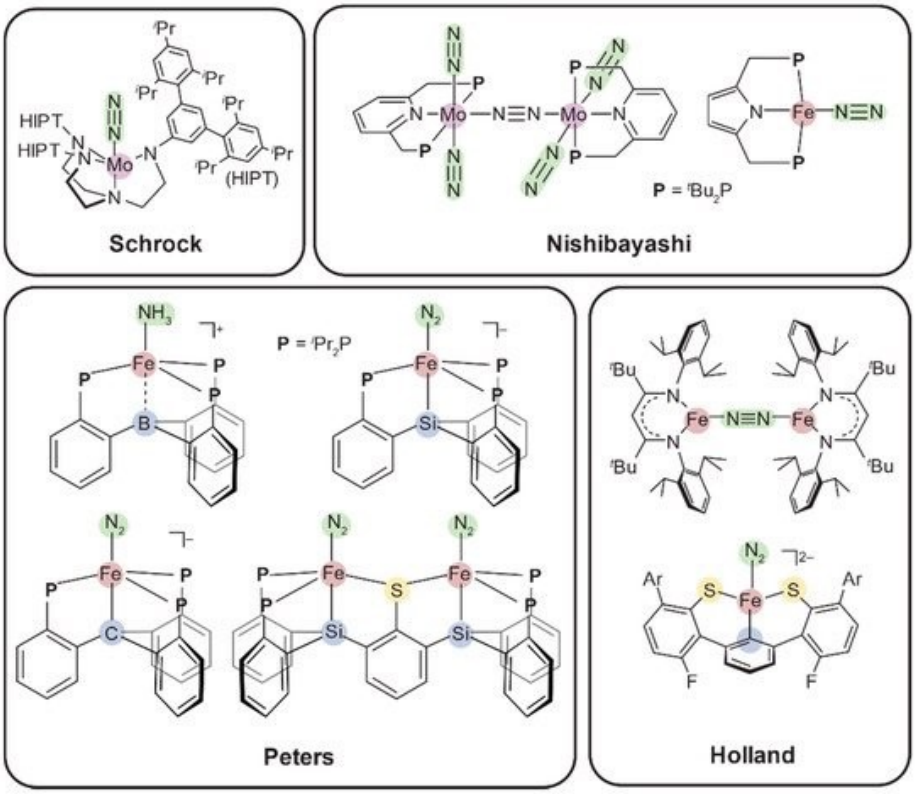


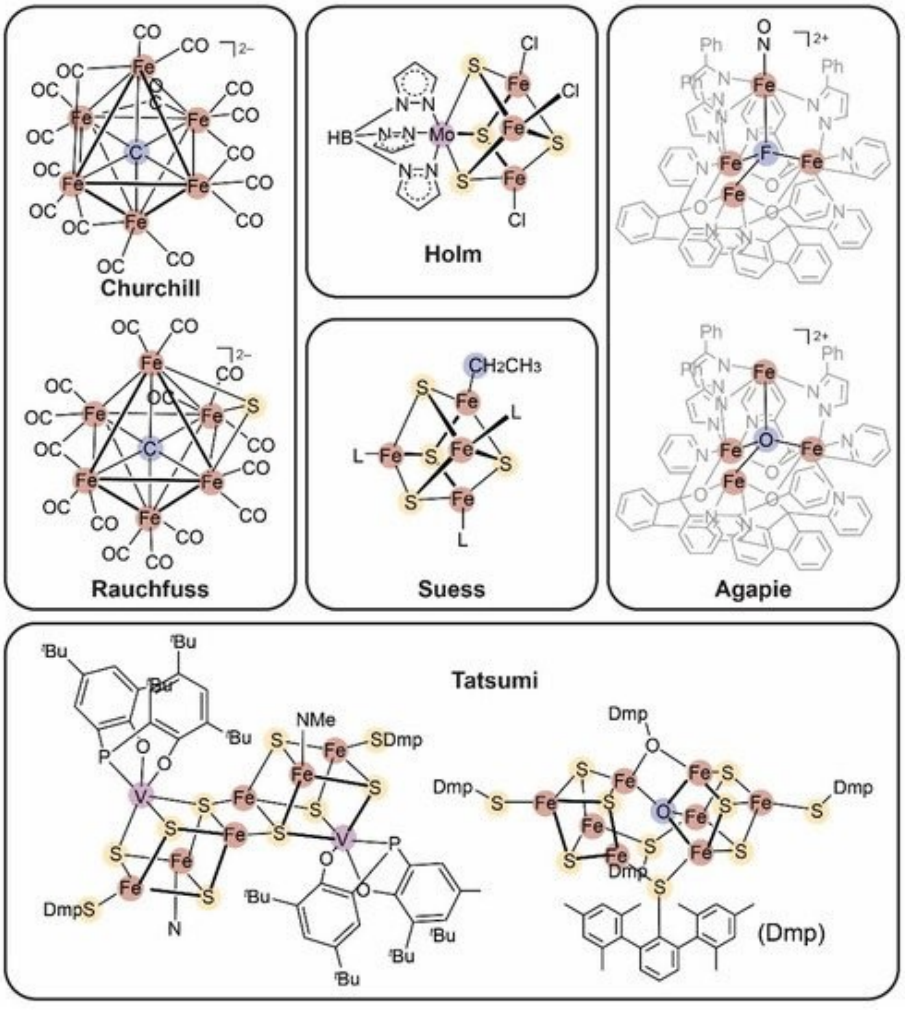
Cat2

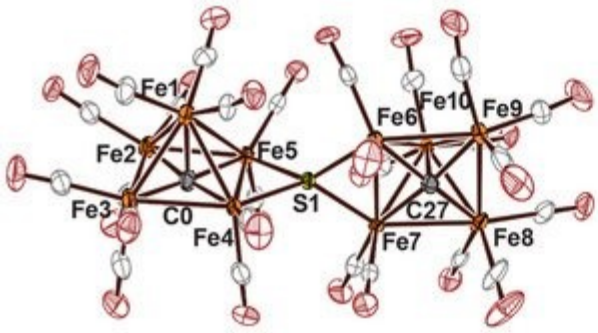


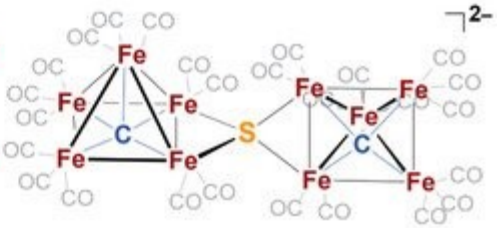
T2R-Cat2

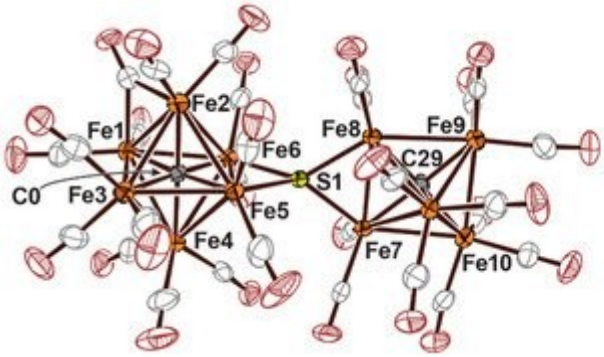


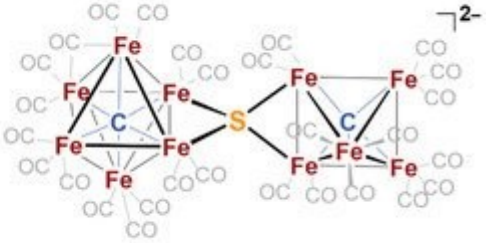

Schrock
Nishibayashi
P = tBu2P
Peters
P = iPr2P
Holland

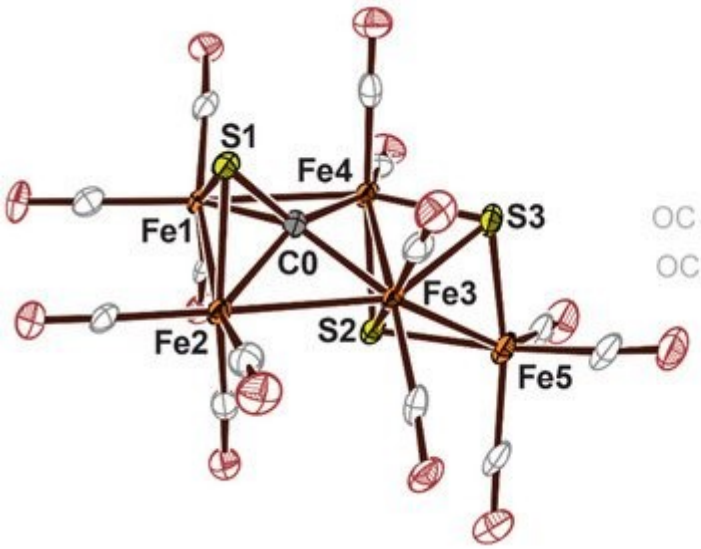

Churchill
Holm
Rauchfuss
Suess
Agapie
Tatsumi
(Dmp)

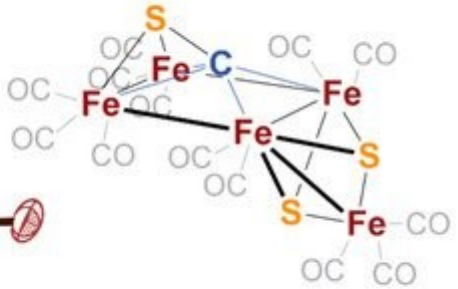

Fe1
Fe2
Fe3
C0
Fe4
Fe5
S1
Fe6
Fe10
Fe9
C27
Fe7
Fe8

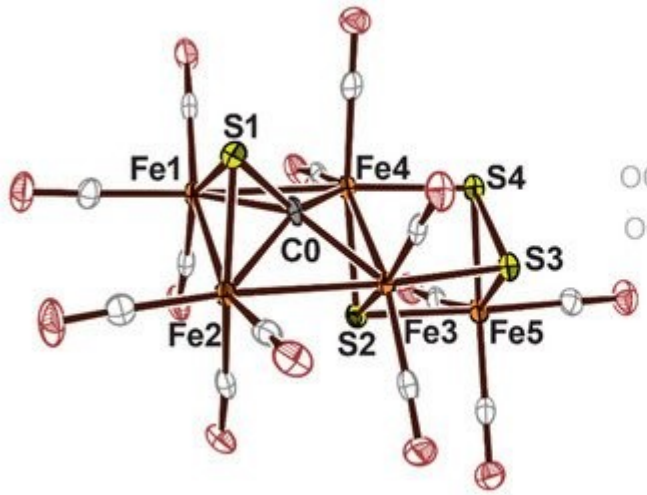

2-

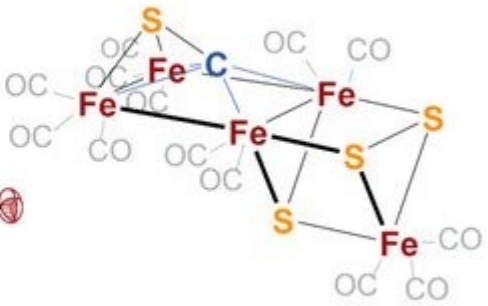

Fe2
Fe1
Fe6
Fe8
Fe9
C29
C0
Fe3
S1
Fe5
Fe4
Fe7
Fe10

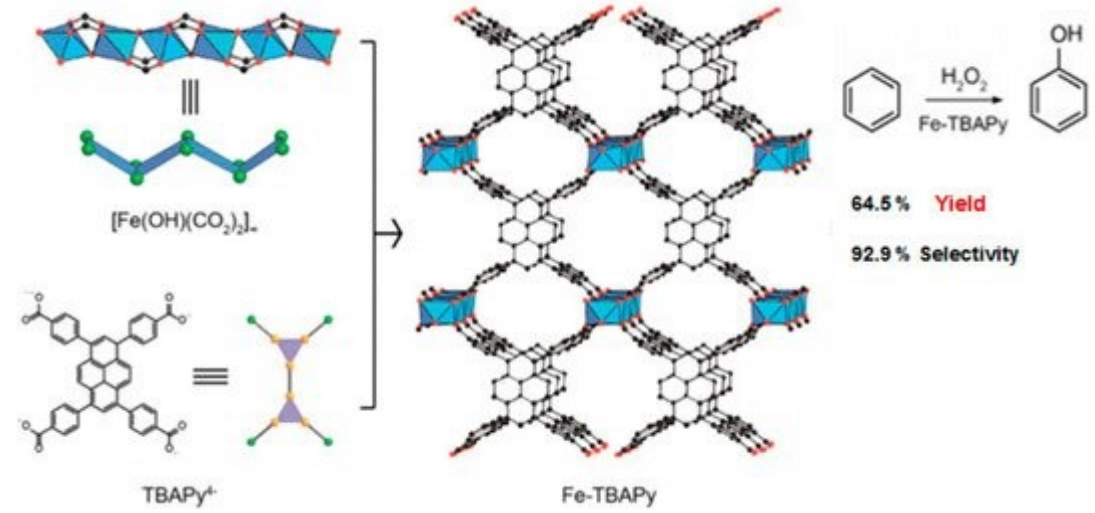

2-

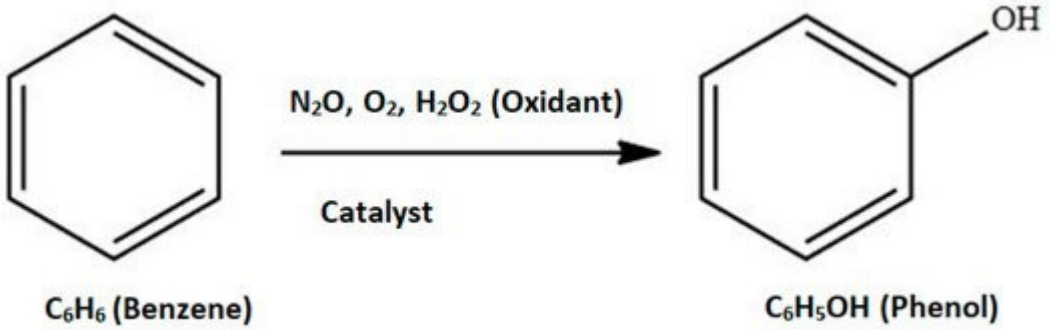

S1
Fe4
Fe1
S3
C0
Fe3
Fe2
S2
Fe5

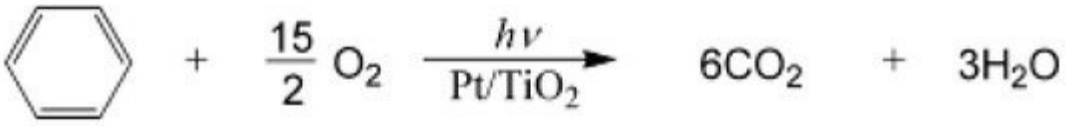


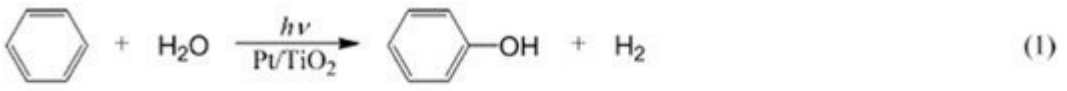

S1
Fe1
Fe4
S4
C0
S3
Fe2
S2
Fe3
Fe5

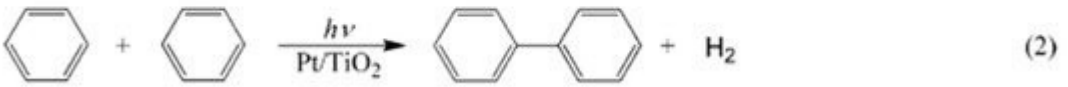


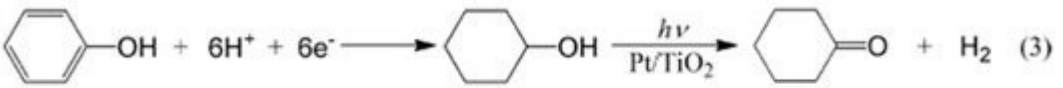

[Fe(OH)(CO2)2]-
TBAPy4-
Fe-TBAPy
H2O2
Fe-TBAPy
OH
64.5 % Yield
92.9 % Selectivity

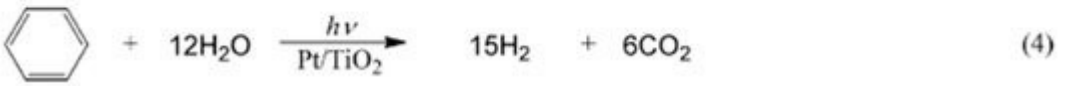

N2O, O2, H2O2 (Oxidant)
Catalyst
OH
C6H6 (Benzene)
C6H5OH (Phenol)

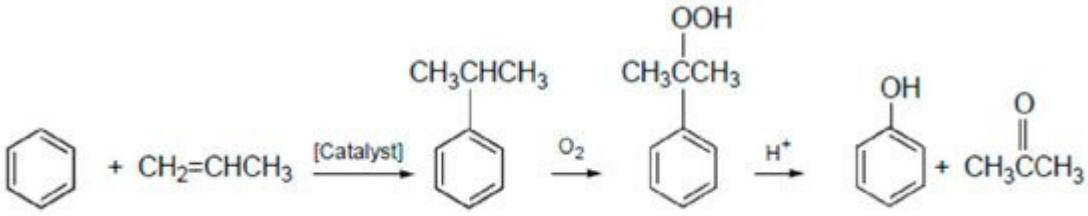

15/2 O2
hν
Pt/TiO2
6CO2
3H2O

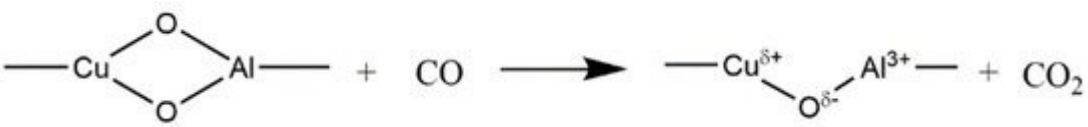

H2O
hν
Pt/TiO2
OH
H2
(1)

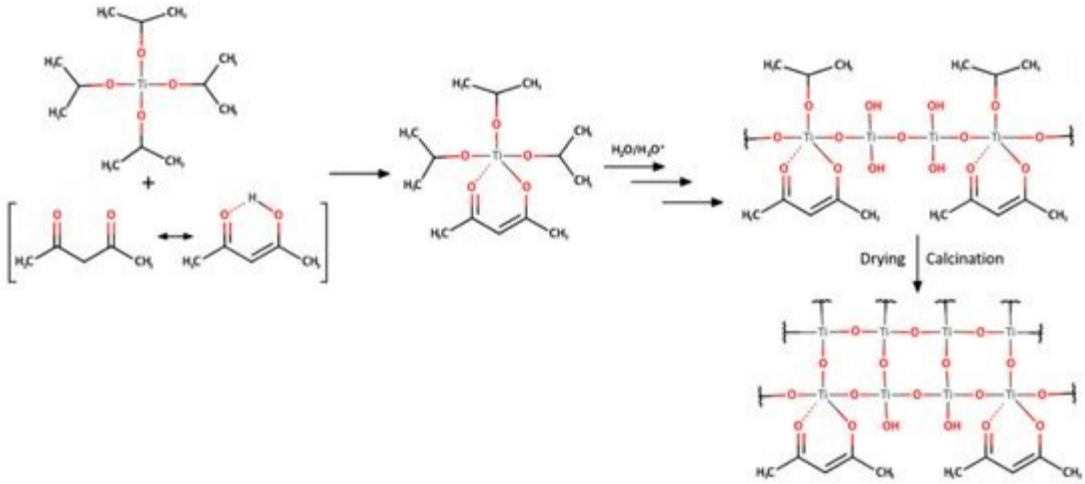

hν
Pt/TiO2
H2
(2)

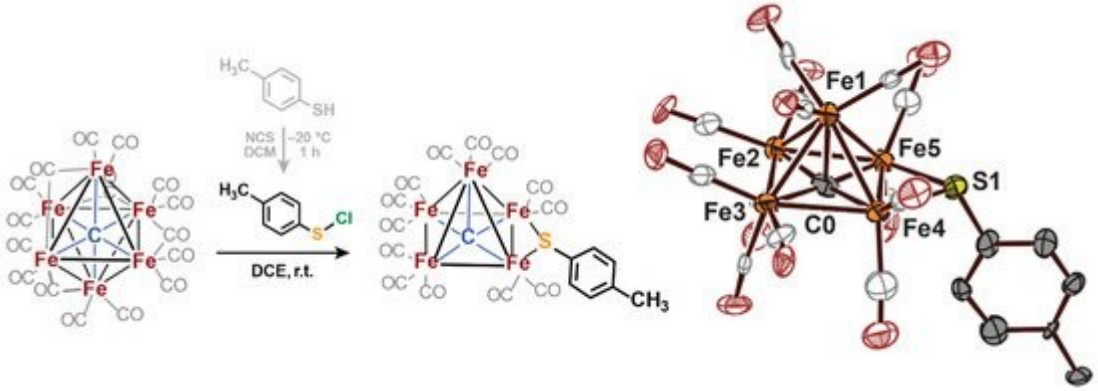

OH
6H+
6e-
OH
hν
Pt/TiO2
O
H2
(3)


12H2O
hν
Pt/TiO2
15H2
6CO2
(4)

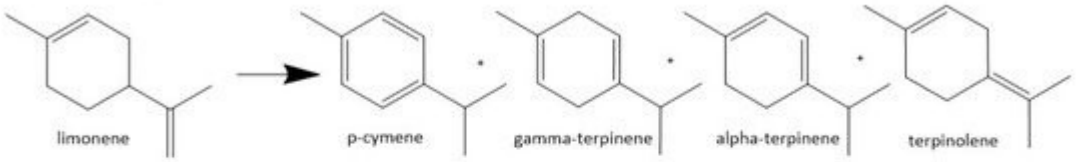

CH2=CHCH3
[Catalyst]
CH3CHCH3
O2
OOH
CH3CCH3
H+
OH
O
CH3CCH3


Cu
O
O
Al
CO
Cuδ+
Oδ-
Al3+
CO2

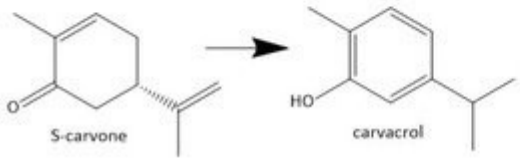


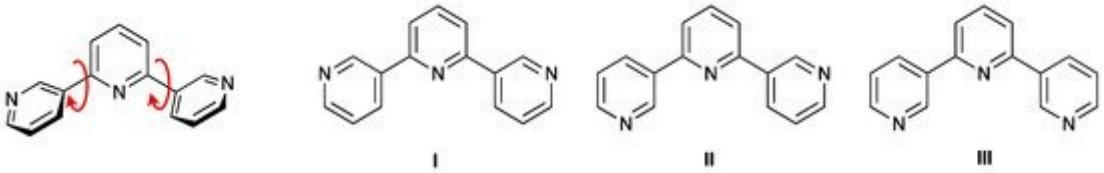


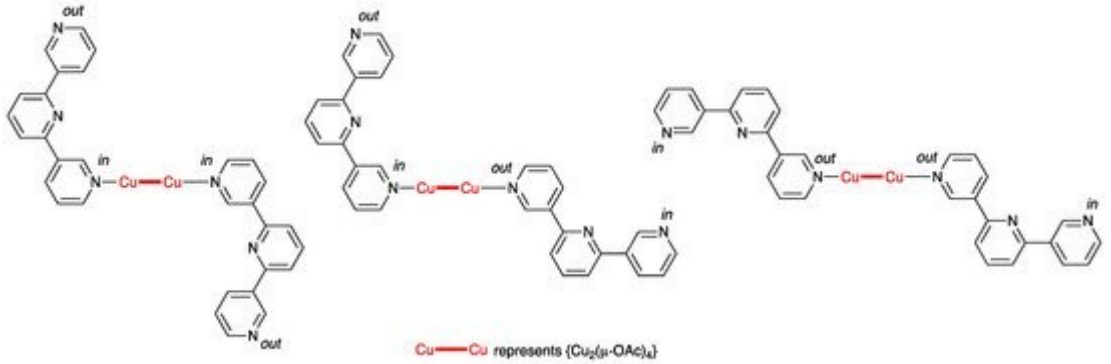
Isomerization of limonene

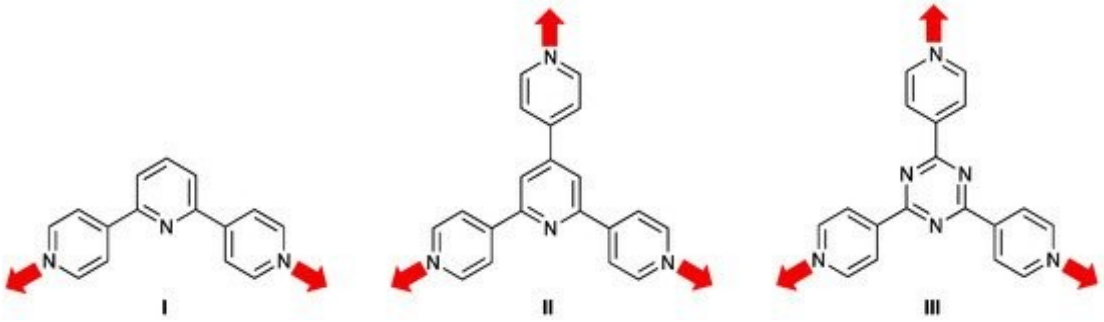


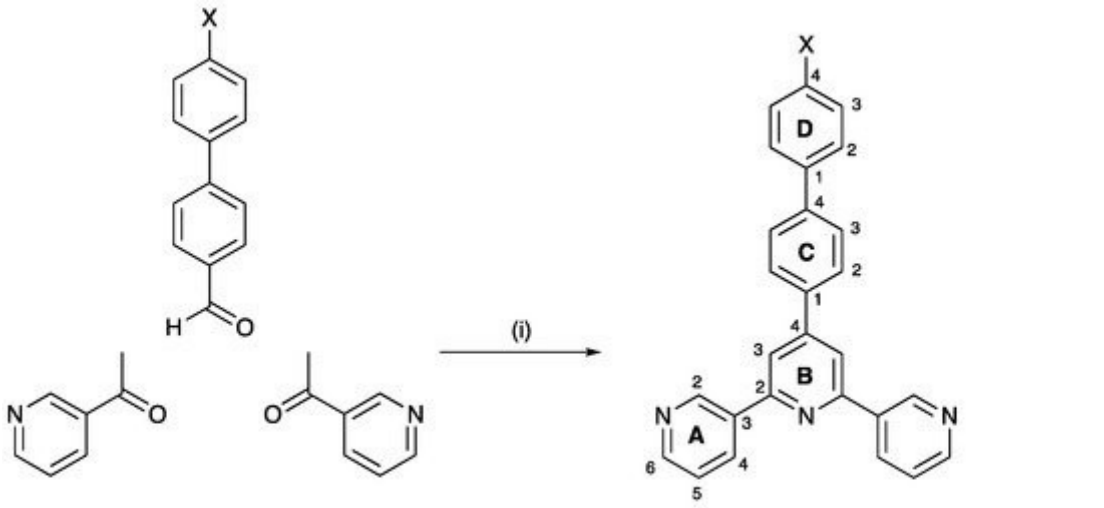
Isomerization of S-carvone



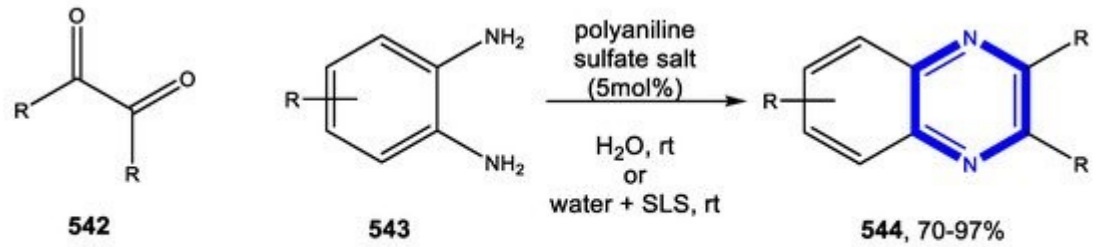






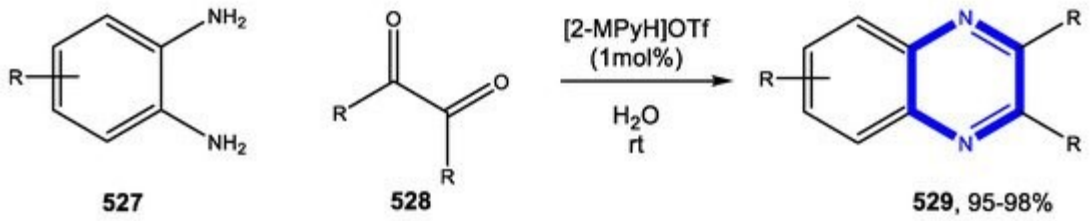


1 X = H; **2** X = F; **3** X = Cl; **4** X = Br; **5** X = Me



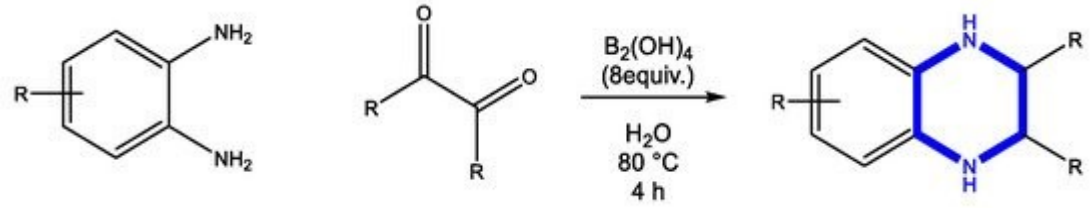
542 **543** **544**, 70-97%

R= H, aryl, heteroaryl



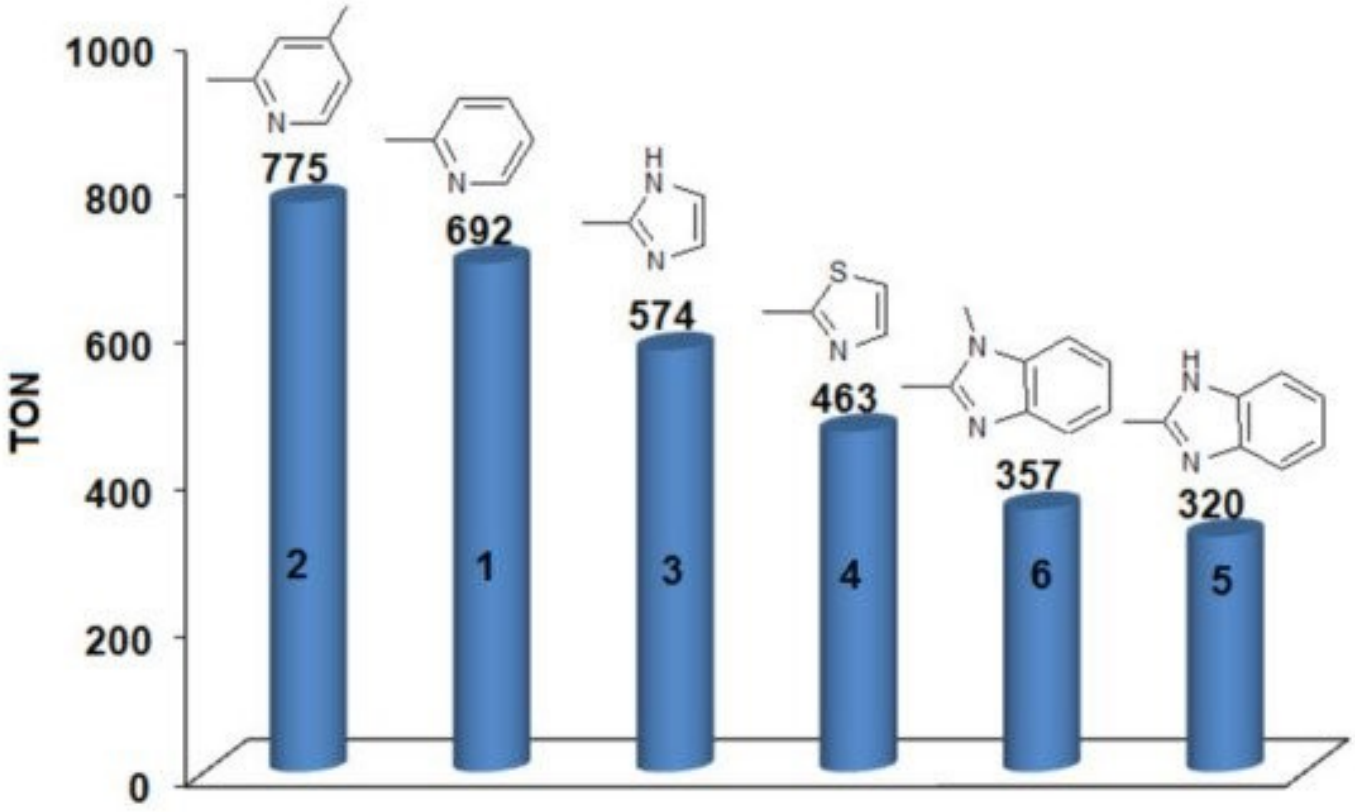
527 **528** **529**, 95-98%

R= H, Me, NO_2 **R**= H, Aryl, Alkyl

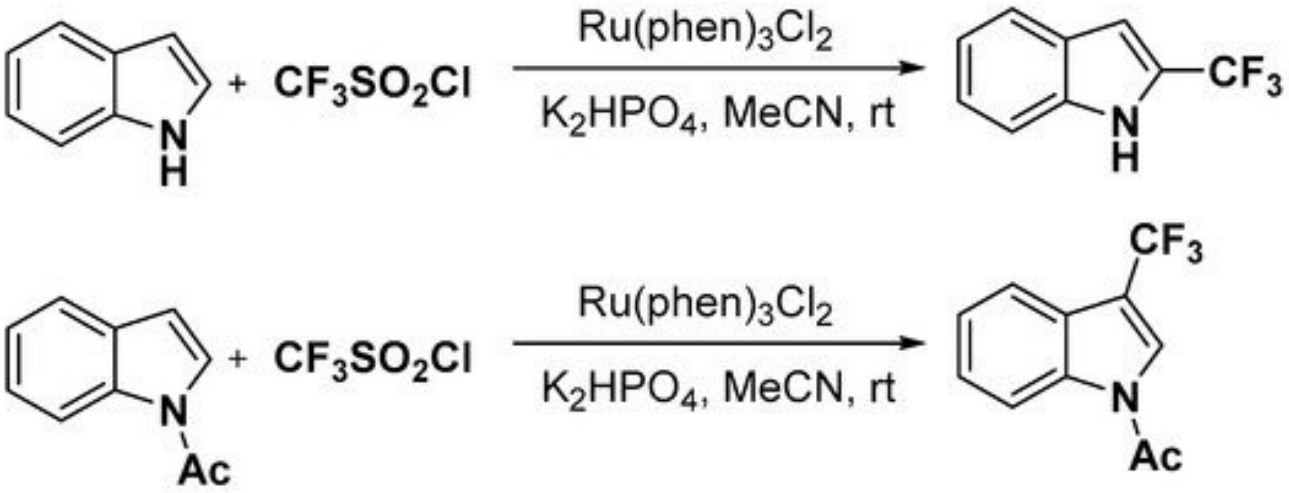


516 **517** **518**, 62-85%

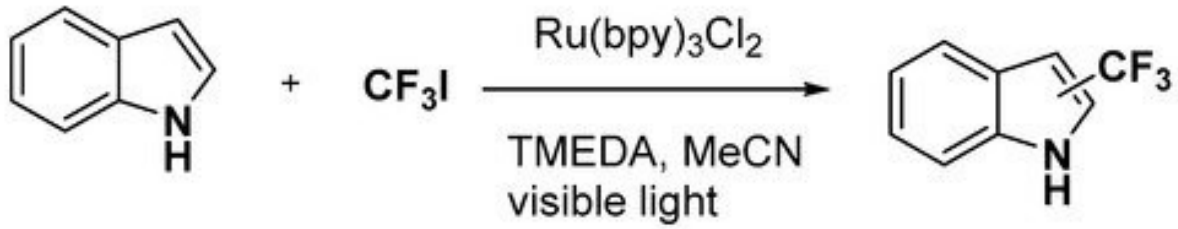
R= H, Cl, Br, F **R**= H, Me, Et, Ph



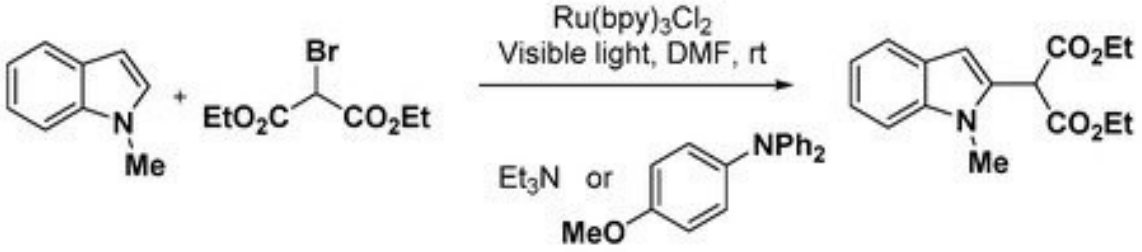
Macmillan's work



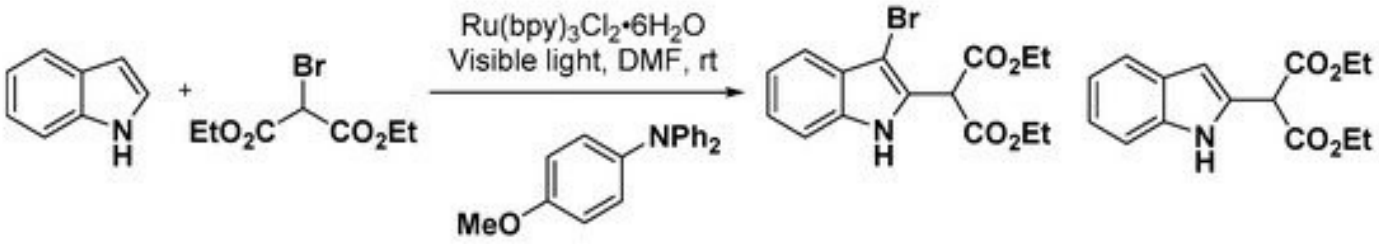
Cho's work

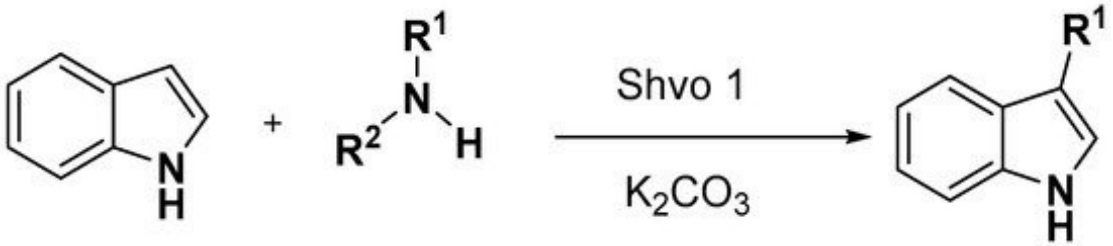


Stephensen's work



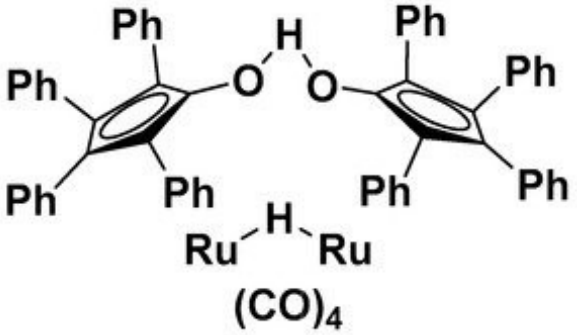
Hansen's work

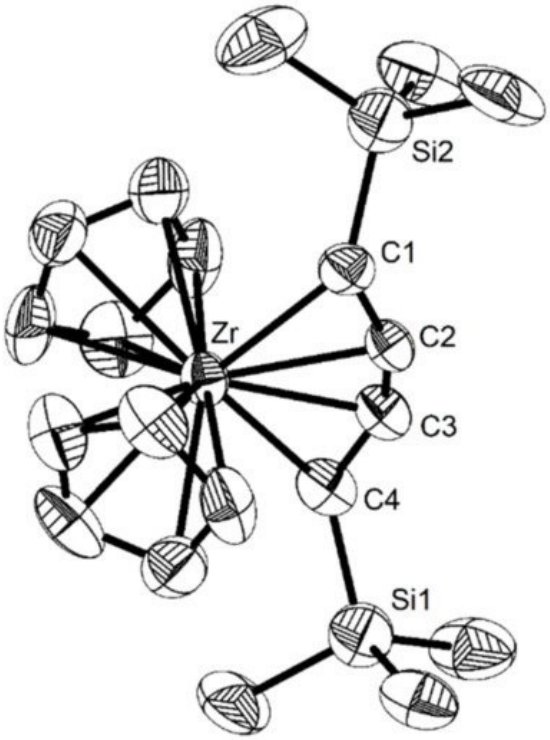


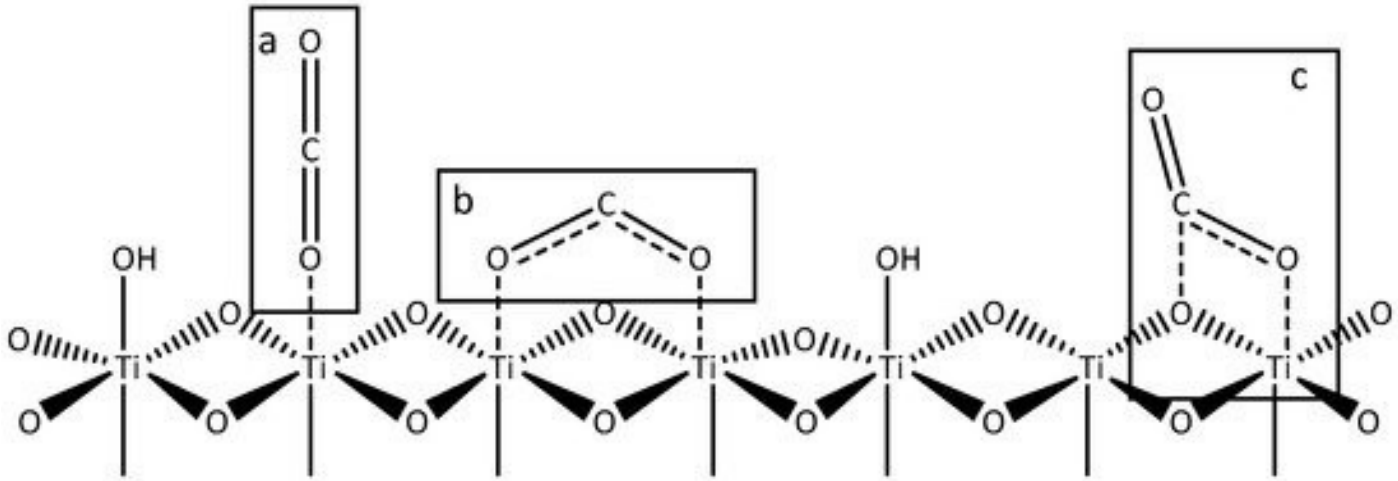


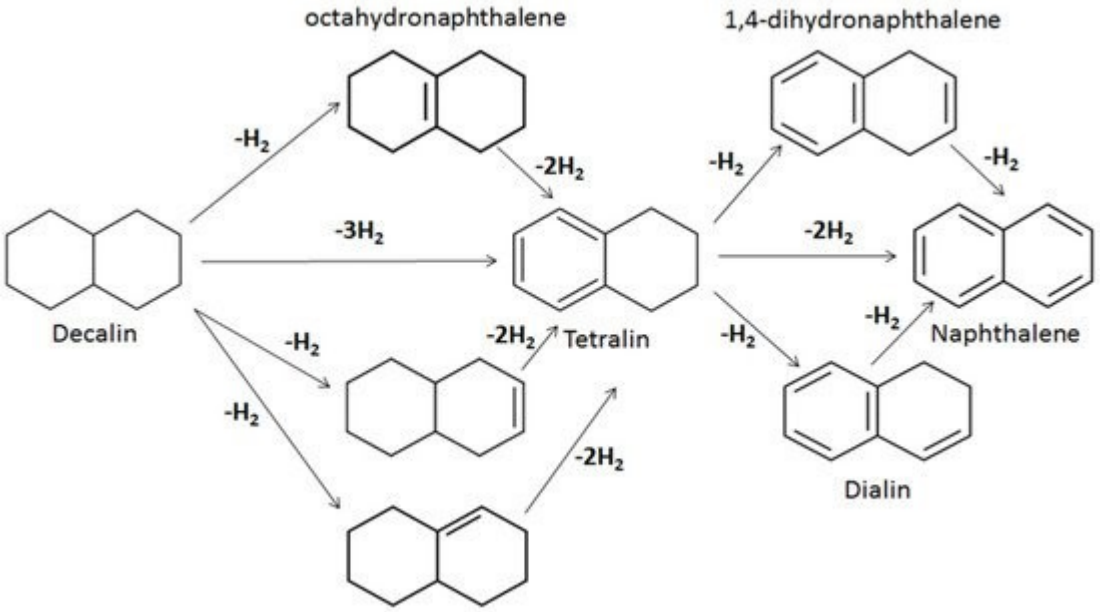
$R^1=R^2=$Alkyl
or $R^2=H$

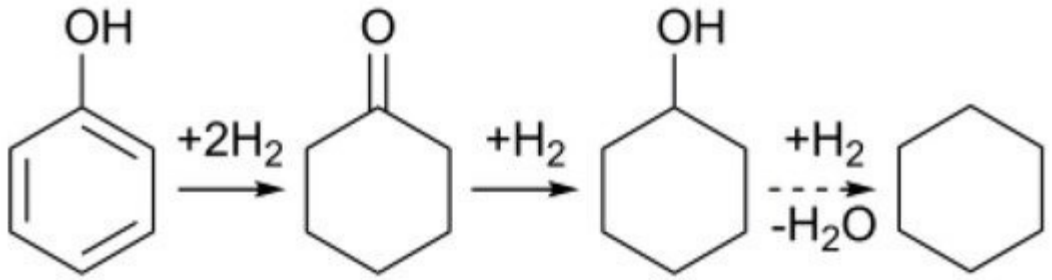
Shvo 1

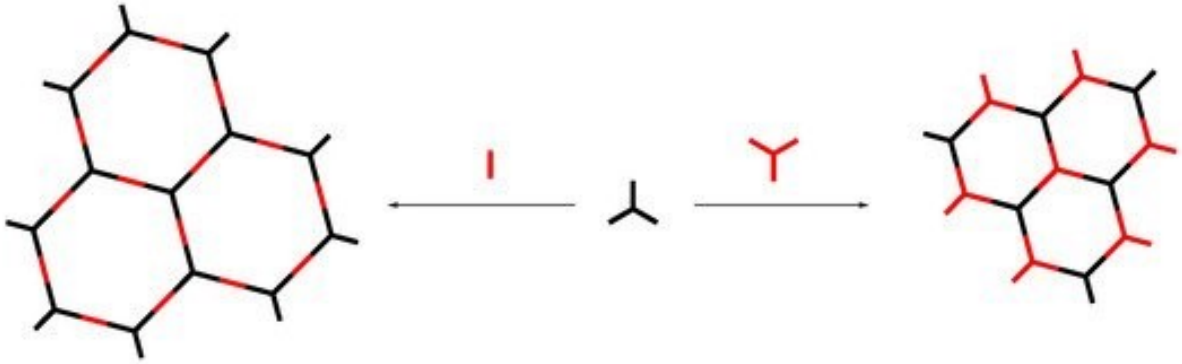


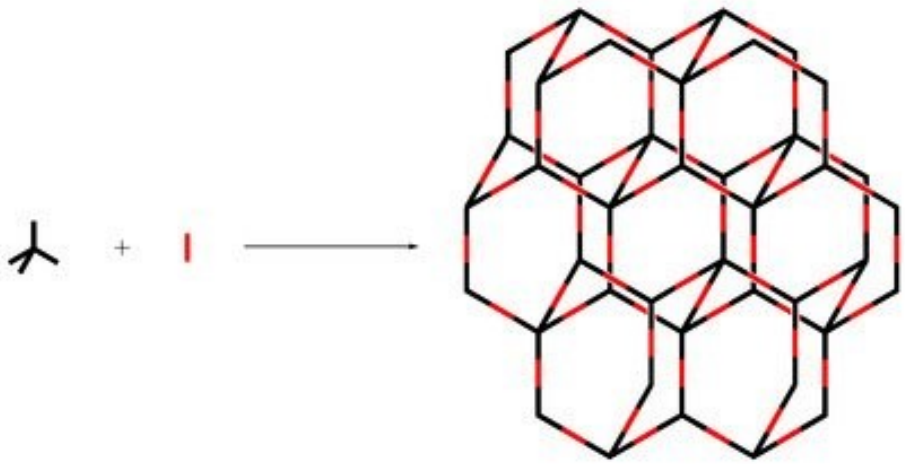


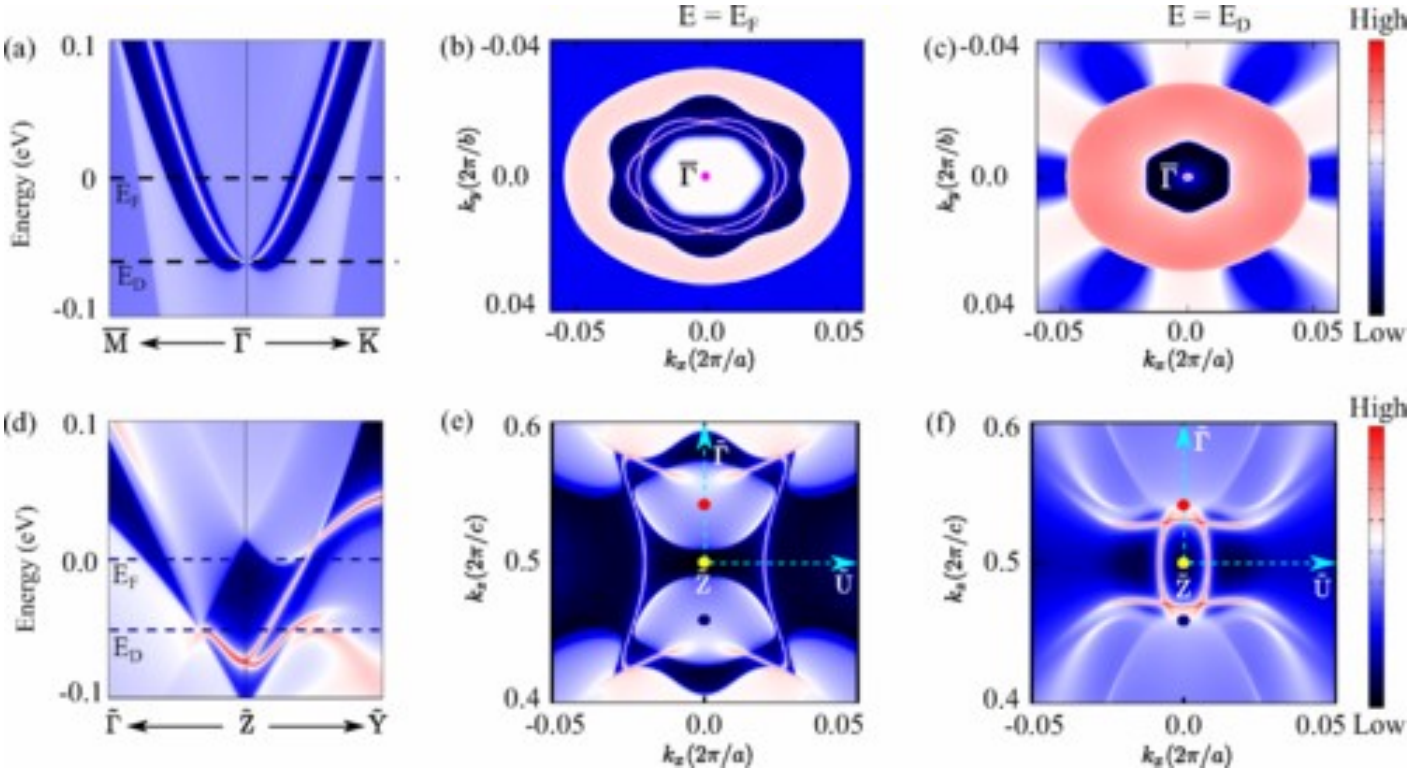


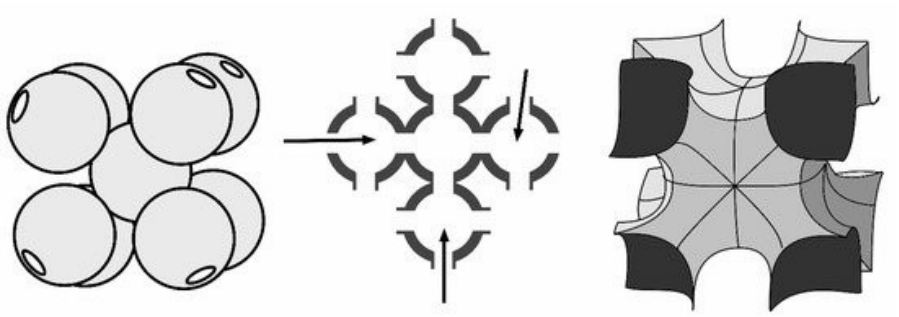

octahydronaphthalene
1,4-dihydronaphthalene
-H2
-2H2
-3H2
-H2
-2H2
-H2
-H2
Decalin
-2H2
Tetralin
-H2
-H2
Naphthalene
-H2
-2H2
Dialin

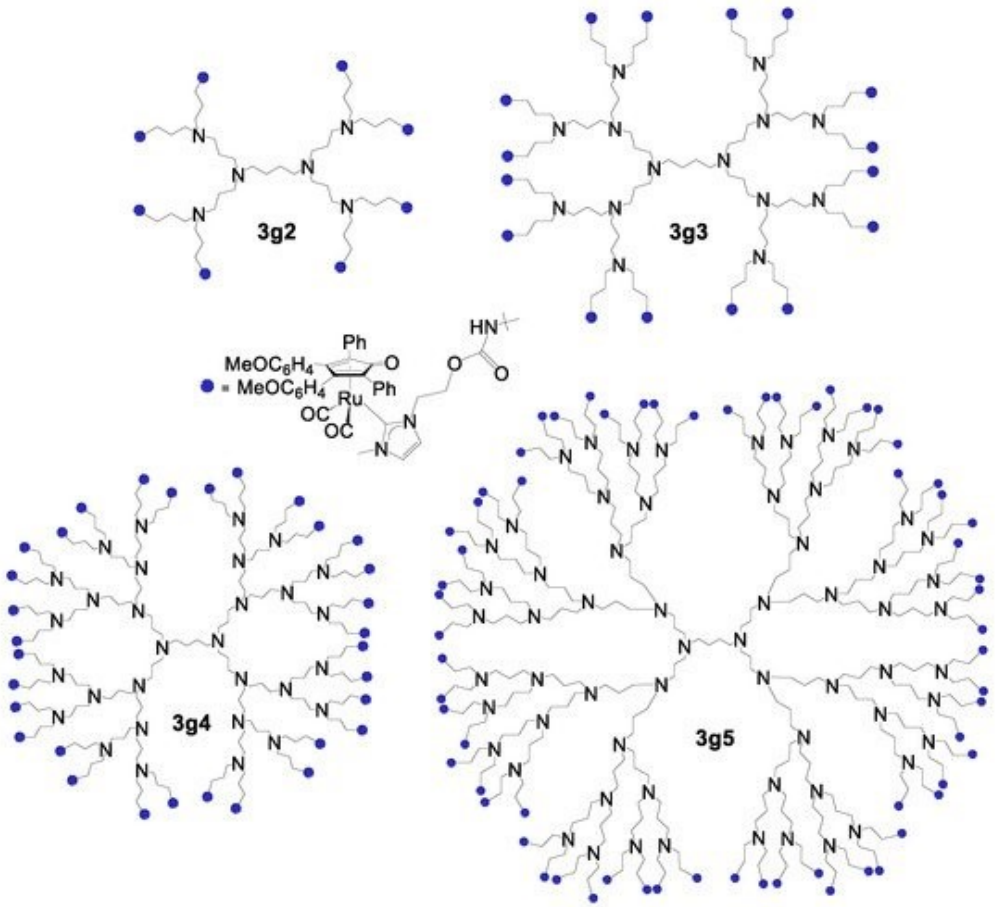

OH
+2H2
O
+H2
OH
+H2
-H2O






(a)
(b)
(c)
(d)
(e)
(f)
Energy (eV)
E = E_F
E = E_D
High
Low
M̄ Γ̄ K̄
Γ̃ Z̃ Ỹ
Γ̃ Z̃ Ũ
k_x(2π/a)
k_y(2π/b)
k_z(2π/c)




3g2
3g3
3g4
3g5
MeOC6H4
Ph
Ru
OC
HN